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The Later Stages of the Cycle of Erosion.

SOME WEAKNESSES IN THE THEORY OF THE CYCLE OF EROSION.

By C. H. CRICKMAY.

THE establishment, toward the end of the last century, of the fruitful conception of the " cycle of erosion " carried with it into general currency certain ideas which rest on no real foundation. Although few, nowadays, would be so rash as to doubt the validity of the cycle idea or to question its value as a principle in geology, few can demonstrate any truth in the accepted pictures of the later stages of the cycle. Geographical old age and peneplanation rest on nothing but pure deduction by a few great masters of geography and geology and a blind acquiescence by the rest of us. I say *blind* advisedly, because only blindness could prevent us from seeing some serious inconsistencies in the picture which have not been generally noticed. These inconsistencies have become increasingly evident in the last ten years. It is time to recognize them.

The orthodox conception of the stages of the cycle of erosion is illustrated in all the textbooks. Even the most modern books offer versions essentially without improvement over those of thirty-five years ago.[1] One recent book makes an advance among textbooks in urging that " land areas may lie just above sea-level for long ages, undergoing hardly any change ", thereby virtually admitting that the erosion cycle may reach completion ; though the thought is spoiled in the next sentence by the unsupported dictum : " cycles are seldom complete."[2]

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[1] F. H. Lahee, *Field Geology*, McGraw-Hill Book Company, 1931.

[2] W. B. Scott, *An Introduction to Geology*, The Macmillan Company, 1932.

The cycle of erosion is commonly represented as passing through stages, as follows:

1. Inital stage: The flat upland or plateau, an uplifted, not yet eroded, plain.
2. Youth: Narrowly V-shaped valleys incised into the flat upland.
3. Maturity, early: Deep, narrowly V-shaped valleys with sharp divides or interfluves.
4. Maturity, late: Broader V-shaped valleys with much less relief and with the beginnings of a flat floor.
5. Old age: The peneplain, an almost featureless plain consisting of low, rounded-off interfluves with scarcely perceptible relief and broad shallow valleys; with, also, a few prominent hills of much greater relief (monadnocks).

The first three stages are well illustrated among the existing scenery of the world, though it is notable that the mature stage, as judged by practical examples, differs from the representation of it in geological theory in one important respect—the occurrence in it of much flat horizontal surface of erosional origin at low levels, namely broad terraces and floodplains. These, though extremely abundant in Nature, have so far found little place in the diagrams illustrative of the cycle of erosion. The two later stages of the conventional representations of the cycle are virtually never seen in actual scenery.

The impossibility of finding peneplains in actual scenery was urged against the peneplain idea by Tarr,[1] though latterly the objection has been forgotten. I now undertake to reiterate it in even stronger terms. The gap that Tarr noted between fact and theory still stands; and, moreover, it is a wider one than has been generally recognized, as will be shown. It includes not only the common conception of the peneplain but that of all the late stages of the cycle.

I must emphasize at this point that no objection has been taken to the cycle idea but simply to the common picture of the course the cycle is supposed to follow in its late stages.

The particular matters of discrepancy may be summarized as follows:

1. Late mature and old age scenery of the sort pictured by accepted theory—that is, low rolling country of faint relief and universally even gentle slopes—is known only where special conditions have brought it into existence—e.g., among the clay plains round Smithville, Missouri, U.S.A., on the soft sediments of the Atlantic coastal plain of the United States, or in small parts of the limestone floors of the Appalachian Valley where solvent denudation of a low flat

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[1] R. S. Tarr, *American Geologist*, xxi, 1898, 351–370.

area is the main factor. Such scenery can not be regarded as a normal development, and has, therefore, no place in the schemata of the cycle.

2. Plains, obviously of an erosional origin, quoted as examples of peneplains, are commonly too nearly perfectly flat to admit of having been produced by peneplanation—that is, by a combination of downward corrasion by streams and wasting. Such a combination would not produce flatness, but rather universally even gentle slopes or, in other words, a peneplain.
3. Some such plains are too irregular to admit of a peneplanation origin; regularity and evenness of slope being essential results of peneplanation.
4. Most plains formerly quoted as peneplains occur in series, at successive levels, one above another—e.g., the terraces of the Appalachian Mountains, the Appalachian Plateau-Highland Rim-Nashville Basin series, the many successive high plateaux of southern Utah, etc. With only the peneplanation theory as a basis for understanding such relationships, it is impossible to see how the lower "peneplains" were formed without the higher ones being destroyed.
5. Monadnocks are an equally eloquent denial of peneplanation. The type example in New Hampshire and most other monadnocks rise high and rugged above the plateau, or plateau remnants, around them. Their stature and their steep slopes are not features of the end-stage of a process of peneplanation: they are utterly opposed to everything characterizing that stage. Where slow reduction by downcutting and wasting has occurred, no monadnock could survive, because it is only during rapid erosion that hard rock is cut perceptibly less than soft. And, indeed, many monadnocks are of material no harder than the rest of the terrain.
6. All actual low relief scenery, which presumably represents the late stages of the cycle of erosion, shows no sign of approach to the peneplain condition; but consists, rather, of two sets of flat surfaces—namely, floodplain and flat-topped interfluve—with short steep slopes between them. The peneplain idea gives no clue as to the meaning of such scenery.

Possibility of Emending the Theory.

It has seemed to me that our theory of the stages of the cycle of erosion has suffered from two matters of defective observation: first, over-emphasis of the power of wasting; second, underestimation of the power of lateral corrasion. The whole theory was worked out at a time when denudation was supposed to be accomplished by three main processes—headward extension of tributaries, downcutting by all streams, and reduction of interfluves by wasting. Since then the power of wasting has been shown to be limited, and a fourth dominant process has been appreciated, namely, lateral corrasion. However, little has been accomplished in studying comparatively the potency of these four kinds of action. Nothing has been done to emend the erosion theory in the light of newer knowledge of them.

THE POWER OF WASTING.

It has been generally assumed, presumably from a contemplation of piles of talus at the foot of cliffs or of deeply decayed bed-rock in regions of warm climate, that wasting is a rapid process. On the basis of this, we are taught to believe that, from the erosional stage of early maturity (when relief is at a maximum) until old age (when it is at a minimum), wasting gains on downcutting and thereby reduces the relief. Certainly, relief is reduced, but there is no real proof that wasting is the principal agent. Indeed, the maintenance of steep slopes into the late stages of the cycle is a strong argument against the effectiveness of wasting. And the occurrence of deep transported soils on steep mountain slopes, as in the southern Coast Range of British Columbia, seems to show that even under favourable circumstances wasting may accomplish but little.

It is instructive to compare, in such places as northern California, the depth of weathering on interfluves with that in canyon walls which are near to an active stream. In this region rock is decayed to a depth of 100 to 200 feet or more, yet anywhere near the path of active corrasion the rock is quite fresh. Plainly, corrasion is far more effective than weathering.

Another sort of example is found in the northern Sierra Nevada of California where ancient though unconsolidated river-gravels still survive the attack of the weather atop mountain ridges, while valleys on either hand have been incised by stream corrasion through 3,000 feet or so of hard bed-rock. Fine examples of this condition are to be seen in the ridges east of Mount Jura, Plumas County.

Again, look at the lava-capped and sill-capped "buttes" of Oregon, Colorado, and other places. They seem to explain themselves readily by the hard lava on top. But, on many of them the lava itself is capped by a deposit of non-resistant sediment or ash. Why did not wasting remove this weak material while it carved out the hard rock on all sides ? Only because it is neither a rapid nor an effective agent except on steep slopes, the bed-rock erosion on all sides having been accomplished by another agent.

A lesson of another sort is to be learned from a comparison of glaciated and non-glaciated regions. In most non-glaciated country the mantle-rock is deep : for instance, in the Piedmont of the south-eastern United States, the interfluves are underlain by 200 feet or so of decayed rock ; in Arctic America exposed rock is rent in fragments to great depths below the surface by frost action. In glaciated regions, on the contrary, such rocks are quite fresh at the surface, even preserving glacial striae in places. Where long exposed since glaciation, to weather of either cold or warm climate, the glaciated surface shows some small changes ; good examples are found in the Coast Range of British Columbia (cold climate) and the Front Range of Colorado (warm). The absence of deep weathering from regions formerly glaciated can mean only that a very small amount of weathering has taken place since the last retreat of the Pleistocene ice. It seems right to conclude that these processes are excessively slow compared with others that contribute to erosion, and that the deep decay of non-glaciated regions has taken for its accomplishment long ages prior to the end of the Glacial Period, indeed so long as to suggest that mere wasting might never be effective in reducing very far the general land elevation.

It is not proper to argue against these conclusions that agricultural land wastes very rapidly unless planted to crops or " cover-crops ". Ploughed land is a very special case of a surface peculiarly prepared for easy surrender to erosional attack. Its breaking down involves no hard rock, and can not be compared with ordinary processes of erosion.

THE POWER OF LATERAL EROSION.

The verity of lateral corrasion has long been known, and even the power of this action to bevel hard rock to flatness was already discerned in 1877.[1] The ideas of base-levelling and peneplanation were built up without it. In the last twenty years, starting with Paige's contention in 1912 for the importance of lateral erosion in planing the flat rock-floors of the desert,[2] and finding support latterly in the studies of E. Blackwelder and of D. W. Johnson in deserts, and of E. B. Knopf in humid regions, lateral erosion has come to be established as one of the dominant processes of denudation.

We might well accept authority, even though there is still contrary opinion, and proceed with the general argument as though the potency of lateral erosion were established. Nevertheless, some examples may be offered by way of confirmation. In the first place, the fact of the existence of floodplains is proof of the power of lateral erosion. Many will reply, because they have not yet thoroughly studied an example, that floodplains are depositional features. This is not correct. Very few floodplains are really of depositional origin. The broad flat area of a normal floodplain is underlain everywhere at shallow depth by planed bed-rock. The alluvium is a mere carpet, usually not deeper than the depth of the stream in flood. Truly, the detail of surface conformation of a floodplain is modelled by sedimentation, but the very existence of the plain is due to the work of the agent which bevelled the underlying rock to flatness. To deny this would be like denying that the house was built by the carpenter, simply because his work is covered in the finished product by that of other sorts of artisans. The true character of floodplains becomes obvious only when they are dissected through a change in the relation of the stream to grade, and are thereby transformed into rock terraces; or when well-borings or drillings reveal the thinness of the alluvial cover, and the flatness or subdued relief of the subjacent bed-rock in contrast to the character of the surface beyond the limits of the floodplain.

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[1] G. K. Gilbert, " Geology of the Henry Mountains.," *U.S. Geog. and Geol. Survey of Rocky Mountain Region,* 1877.

[2] Sidney Paige, *Journal of Geology,* xx, 1912, 442–450.

Again, the fact that stream meandering results in the formation and maintenance of steep high cliffs, here and there, shows that horizontal cutting is so rapid in such places that the destructive action of weathering on the cliff is scarcely noticeable. The spreading and downstream migration of incised meanders are not unfamiliar phenomena. Most of the rivers of the northern Great Plains of North America exhibit these conditions, and thereby bear testimony to the potency of lateral cutting by meandering streams. A broader survey of the borders of a large stable floodplain shows everywhere either a fresh cliff or a slope steep enough to tell plainly of a cliff but recently fallen into ruin. The observation of about 9,000 miles of floodplain borders convinces me that cliffs in these places are as nearly continuous as cliffs on sea-coasts. This means that lateral erosion is, on the whole, as important as wave erosion.

Some special examples of various sorts may be added. There are places where streams have, flowing in entrenched meanders, cut through the narrow necks of land between meanders so fast that the rock remains as an arch over the new diversion of the streams current. The famous natural bridges of southern Utah were formed by this action. The time required to form them was plainly but a fraction of the time needed for weathering to wear them down.

The Tujunga River, a weak, aggraded, and in places intermittent stream of southern California, was raised to high flood in the spring of 1928, with the result that for a few days it changed its character utterly, and meandered powerfully. In the course of two and a half days one favourably placed meander undermined over two acres of ground, and removed about 150,000 cubic yards of earth, sand and boulders, destroying road-pavement and orange groves. Similar examples might be multiplied indefinitely.

THE RELATIVE POWER OF FLUVIAL EROSION AND WASTING.

One of the most convincing arguments, to show how vertical and horizontal erosion by streams may outstrip wasting, is supplied by the preservation of ancient physiographic features at high levels. For an example, E. B. Knopf concludes from a study of residual erosion surfaces in the Appalachians that "on existent divides remnants of surfaces cut during previous cycles are more or less immune from the destructive agencies of the present cycle". And again, in reference to wind-gaps, "their present outline has been comparatively little modified since the time when water was flowing through them, because they are hung up, so to speak, out of reach of subsequent erosion." The implication of this, in my interpretation of it, is denial that wasting has any great part in denudation, for the agents of wasting are universal and no exposed part of the earth's surface is immune to their exertions. A second implication is that erosion proceeds from *below,* from actual drainage-lines. The interfluve is not reduced by wasting except where it has been given steep edges by the activities of the streams, and it will survive indefinitely except for this action of paring away at its edges.[1]

In the area studied by Knopf, there are several nearly flat horizontal erosion surfaces one above another. The highest one and other extensive ones have usually been called peneplains, the lowest and all the smaller ones have been called terraces. None below the uppermost can well be a peneplain, because it is obviously impossible for some features of a former cycle of peneplanation to remain unchanged while most of the features of that cycle are not only changed, but almost utterly destroyed. It is impossible that the higher peneplains could survive unaffected by the wasting that is supposed to have worn down the lower ones. Quite plainly, as Knopf concludes, the "peneplains" were formed rapidly, one after another. The rational interpretation is that they are remnants of ancient floodplains, carved by lateral corrasion (the only agent except waves that acts both rapidly and horizontally) during several successive stages of graded conditions among the streams of this region.

The terraces of the Appalachians are diminutive compared with those of certain other mature regions, for instance, south-western Wyoming. This remarkable country is made up almost entirely of terraces and cliffs. The baffled student, with the accepted ideas of erosion stages strong in his mind, vacillates between calling it youthful or peneplaned. Yet it is neither, for there are an indefinite number of "peneplains" one above another. None of these are truly peneplains. They are simply remnants of floodplains, carved on the surface of various hard formations which by their hardness caused a temporary graded condition. They have long since been deserted by the streams that formed them, but they stand little changed by all the wasting that has proceeded during many subsequent cycles of floodplain-cutting.

A superb example of the preservation of ancient erosional scenery is seen in the Cypress Hills of western Canada.[2] In that locality an old erosional plain, preserving the ancient stream-channels and their banks with exquisite fidelity, has survived atop the Cypress Hills while the Great Plains have been cut away on all sides, and bevelled to flatness 1,000 feet below. Here, as elsewhere, wasting has left the upland untouched while a vast erosion has been consummated all around it. Here, again, it is impossible that the carving of the plains to flatness was accomplished by anything but corrasion by running water, and that necessarily involves two sorts of corrasion—vertical and lateral.

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[1] E. B. Knopf, *Bulletin Geol. Soc. America,* xxxv, 1924, 636–666.

[2] C. H. Crickmay, *Canadian Field-Naturalist,* xlvi, 1932.

AN ATTEMPT TO ENVISAGE GEOGRAPHICAL OLD AGE.

If this reasoning on wasting and lateral erosion be correct, the results of lateral erosion must loom increasingly large as denudation wears on, and other processes are proportionately slowed up. It is right to say, on the basis of common observation, that by the time of attainment of maximum relief the streams will be in large part graded. This will result in the formation of floodplains, slightly at first but increasingly as time goes on. From then on, rejuvenations may be expected to interfere with simple progress, and floodplain remnants will be left as terraces on the valley walls. As denudation proceeds the relentless spread of lateral planation will be expected to wipe out many of the original interfluve ridges, leaving flat surfaces in their place. The incidence of rejuvenation may bring the same interfluves into relief again. This will be followed by the development of wider terraces below.

Thus, full maturity will be characterized by much flat surface at various levels, with persistently steep slopes between. Valleys will be shallow, and will have flat floors of a width depending on the length of time they have been undisturbed. Remnants of interfluve ridges will remain as monadnocks. This is represented by the Nashville Basin of Tennessee and the country round it. In a region of folded stratified rock, dip-slopes will be a dominant note in the scenery. Late maturity will be the same, only with wider areas of flat plain both across divides and in valley bottoms, and less relief. This stage, referred to as a problem on page 339 under the 6th objection to the peneplain idea, is represented by the Salem Platform of Missouri and certain low parts of the Piedmont of the Atlantic States.

Now let us assume that the crust will stand still long enough for the cycle to complete itself. General reduction of elevation will decrease the gross detrital load cast upon the drainage, which in turn will bring grade closer and closer to base-level. The tendency to cut floodplains graded to sea-level, started in an earlier stage, will now become dominant ; and, starting from the lower courses of rivers, floodplains will eat their way into the area of the remaining high ground. This is the stage of old age. At the end of it we would expect the growing floodplains to become confluent, making one broad universal plain shared by all the streams of the region. The surface will be flat, and will have a general slope like that which now characterizes the lower floodplains of great rivers. The only relief will be remnants of some of the interfluves which may persist as low monadnocks. This plain, formed of floodplains joined by their own growth, may be called a *panplain.*

Final Considerations.

The question will at once be raised: why are panplains now forming over so small an area? The answer is that the modern continents have, in recent geologic time, been quite abnormally disturbed. This has taken the form of high elevation and a shifting of all the largest rivers into areas of subsidence or still-stand. In consequence, panplanation has been attained only in a limited way; and in few places is its verity obvious.

In deserts, where the water supply is scanty and spasmodic, the gradient of grade is much higher, and consequently is much sooner reached by the degrading stream. As a result, panplanation of a local sort becomes evident sooner than in humid regions. Thus we have the rock-floors of the desert, known as pediments and panfans. These are exactly homologous with panplains, just as inselberge are with monadnocks. I think Davis[1] is quite mistaken in comparing pediments with a supposed intermediate slope between valley-floor and valley-wall in humid regions, and Blackwelder[2] is partly wrong in making panfans the desert counterpart of peneplains. It is only right to add, however, that Professor Blackwelder's work has been my constant inspiration.

The beginnings of the panplain date from an early stage in the cycle, and hence a considerable area may be panplaned before other parts of the region are beyond maturity. Panplains formed before the entire region is reduced will be somewhat higher and more sloping than those formed later, because grade is sustained somewhat higher by a heavier load of detritus. In due course, these earlier panplains will be pared away by the growth of the later ones, and in the course of their going will exactly resemble low terraces being undermined by the enlargment of any river floodplain. This control of physiographic development by grade is a key to an understanding of the remarkable, though commonly forgotten, fact that over three-quarters of the earth's surface is nearly flat, almost horizontal; and most of the remaining one-quarter is of steep, rather than gentle, slopes.

The essential difference between panplanation and peneplanation is that the former starts from the lower floodplains of rivers and grows laterally in all landward directions, whereas the latter is of universal occurrence. Presumably, the former is so much the more rapid that the latter would rarely, if ever, reach completion. This is a key to the understanding of scenery made up of " peneplains " at different levels one above another, and also of the survival of monadnocks.

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[1] W. M. Davis, *Journal of Geology*, xxxviii, 1930, 1–27, 136–158.

[2] E. Blackwelder, ibid., xxxix, 1931, 133–140.

AN INTERNATIONAL RAPPROCHEMENT.

For a long time, British and American geologists were disagreed as to the mode of formation of corrasional plains : the former favouring wave-action ; the latter, a combination of vertical corrasion and wasting. Though no real controversy took place, and for a long time no great interest has been focussed on the question, there is still, though well concealed by international courtesy, a firm divergence of opinion. It now seems possible that a due recognition of the part played by lateral erosion may be the key, not only to a better understanding of scenery in terms of dynamic geology, but also to an international rapprochement in the interpretation of erosional plains.

THE DURATION OF THE EROSION CYCLE.

We are told, especially by physiographers, that we are not to think of the cycle of erosion in terms of exact periods. None the less, the geologist, feeling the need of bringing all possible exactness into his inexact science in order to attain quantitative results, turns toward the thought of how long, in familiar units, is the cycle of erosion. Calculations on the basis of present day rates of denudation, based in turn on the load of great rivers, have suggested that the modern continent of North America might be base-levelled in 15,000,000 years.[1] Barrell [2] provided a factor for the supposed slowing up of erosion in old age which would lengthen the time required for base-levelling to 30,000,000 or 50,000,000 years. Observation shows this to be much greater than the periods of " peneplain " cutting of which we have record. For instance, none of the Appalachian " peneplains " are much older than the latest Cenozoic.[3] Also, it is much greater than the periods of base-levelling recorded in unconformities.[4] Some Jurassic unconformities in western North America record periods of base-levelling of about 1,000,000 years. Moreover, it is well known that there are a number of successive base-levellings recorded in the Cenozoic of California. If the whole Cenozioc is only 50,000,000 years,[5] none of these base-levellings can well represent much more than 5,000,000, and more probably nearer 1,000,000.

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[1] R. B. Dole and H. Stabler, Water Supply Paper, 234, *U.S. Geol. Survey*, 1909.

[2] J. Barrell, *Bulletin Geol. Society of America*, xxviii, 1917, 745–904.

[3] E. B. Knopf, *Bulletin Geol. Soc. America*, xxxv, 1924, 635–6.

[4] C. H. Crickmay, "Jurassic Unconformities," *American Midland Naturalist*, 1933.

[5] *Bulletin National Research Council*, 80, Washington, D.C., 1931.

Panplanation is the key to understanding these discrepancies between the expected and observed rates of erosion. Since base-level may be approximated in one place long before the great task of reducing the continent is even well advanced, the cycle may be, to all appearances, completed in that one area in a small fraction of the time needed for the greater task. The time required for the panplanation of a region may be expected to be in some measure proportional to its area. If a cycle involves greater area, it will require more time.

Finally, it seems unlikely that there will be any great slowing up with old age. Lateral erosion is strong as long as a river is at grade and has a sufficient supply of water, no matter how low the gradient. The Mississippi, on which the calculations of the rate of erosion were based, transports its load through reaches in which the gradient is only 1 inch in 1 mile. With gradients only slightly above this, it meanders powerfully and adds to its already enormous load. There is, therefore, every reason to expect that the continent may be reduced at the present day rate in great part to a flat plain, not at a gradient of 1 inch in 1 mile, but at gradients continuous with this, being a little steeper inland in consequence of the smaller currents of tributaries and headwaters.

On *Lepidocyclina* (*Lepidocyclina*) *atascaderensis* Berry from the Atascadero Limestone (Eocene) of N.W. Peru.

By J. U. Todd, B.A.

(PLATE XVIII.)

IN 1930 Willard Berry published a paper on the Lepidocyclines of the Atascadero Limestone,[1] for which he erected five new species, two of which were megalospheric and three microspheric.

An examination of abundant material and no fewer than 207 sections of the Lepidocyclines of this rock, however, leaves no doubt in the writer's opinion, that there is but one species present showing a considerable range of variation and of which there is an almost equal proportion of megalospheric and microspheric forms, the latter being, perhaps, slightly more abundant. Thus the first name that Berry proposed is taken to include the lot.

A careful examination of Berry's paper shows that he has apparently erected each species on a single horizontal section and a single vertical section, since precise measurements to one-tenth of μ are given in each case, with no range of variation whatever. In sectioning there is always liable to be a variation due to the failure of obtaining an exactly median section, and a slightly oblique section may make a difference of several μ, even though it shows all the equatorial layer chambers.

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[1] Willard Berry, "The Larger Foraminifera of the Atascadero Limestone of North-West Peru, S. America": *Eclog. Geol. Helv.*, 1930, xxiii, 490 et seq.

In these circumstances it becomes necessary to redescribe the single species which occurs in the limestone so that it may be recognizable and of value to workers in South America.

Lepidocyclina (*Lepidocyclina*) *atascaderensis* Berry.

1930. *L. atascaderensis* Berry, *Eclog. Geol. Helv.*, 23, 1930, pp. 490 et seq.

Synonyms.—
L. columna Berry, loc. cit.
L. brightoni Berry, loc. cit.
L. carmani Berry, loc. cit.
L. nuttali Berry, loc. cit.

Material.—C. Barrington-Brown collection, Sedgwick Museum, Cambridge. Rock slices C. 539–542 and C. 545–6, and slides C. 532–6 and C. 543, showing sections of 207 specimens, from forty of which measurements were taken.

Two of the hand specimens, C. 528 and C. 538, available for examination, had been lent to Berry, who recognized them as coming from the same horizon as his material, and from one of these thin sections were made, while from the other, which he figures in his paper, a few individual specimens were extracted from the reverse side.

Horizon.—Atascadero Limestone (Eocene).

Locality.—Atascadero, N.W. Peru.

Description.—The test is circular, lenticular, with a small flange-like portion at the periphery, and papillate over the whole surface. The numerous papillae are small, being about 55–60μ in diameter, and are scattered over the whole surface without any particular arrangement. Megalospheric and microspheric forms are present in almost equal abundance. The diameter of fourteen specimens of the megalospheric form varies from 1·7 to 3·1 mm. with an average of 2·6 mm., and the thickness varies from 0·4 to 0·86 mm., with an average of 0·7 mm. This gives a ratio of diameter to thickness of 2·7–4·2 to 1.

The diameter of twelve specimens of the microspheric form varies from 2·1 to 3·5 mm., with an average of 3·3 mm., and the thickness through the centre varies from 0·64 to 1·06 mm. with an average of 0·74 mm. The ratio of diameter to thickness varies from 2·6 to 6·3 to 1. The thin flange-like portion is composed of equatorial chambers uncovered by lateral chambers and is usually from 55 to 80μ wide.

Equatorial Sections.

In the A form (Pl.XVIII, Fig. 3) the embryonic apparatus is composed of two nearly equal chambers divided by a slightly curved septum. The total length of the apparatus is 188–233μ with an average of 212μ, and the greatest breadth is 130–167μ with an average of 134μ. These measurements include the embryonic walls which are 11–18μ thick. The equatorial chambers are usually open arcuate, though occasionally they appear hexagonal. An average measurement for chambers about $\frac{3}{4}$ mm. from the centre is 60–75μ radially and 65–80μ tangentially, and they are separated by walls 11–15μ thick.

In the B form the embryonic apparatus consists of a small spherical initial chamber followed by a spiral of six chambers. The equatorial chambers are open arcuate to hexagonal and at about $\frac{3}{4}$ mm. from the centre measure 65–70μ radially by 70–85μ tangentially with dividing walls 11–15μ thick.

VERTICAL SECTIONS.

In the A form there are about eight to twelve layers of lateral chambers over the centre, and about the same number in the B form, though the latter may have thirteen to fourteen layers. The layers are divided by walls 18–22μ thick, though occasionally they may be 30μ thick. The lateral chambers over the dome and near the surface have measurements of 18–25μ vertically by 45–90μ horizontally. Pillars are present which thicken as they approach the surface where they end as papillae about 55μ thick. The embryonic apparatus is 130–185μ high in the A form and the equatorial layer increases steadily in thickness from about 35μ thick at the centre to about 75μ thick at the periphery in both forms, the walls separating it from the lateral chambers being 15–18μ thick. In the more perfect specimens, where the flange has not been destroyed, the equatorial layer may be as much as 120μ thick at the periphery.

TANGENTIAL SECTIONS.

The lateral chambers are irregularly polygonal in outline and have no definite arrangement. Numerous pillars are present, though these are small.

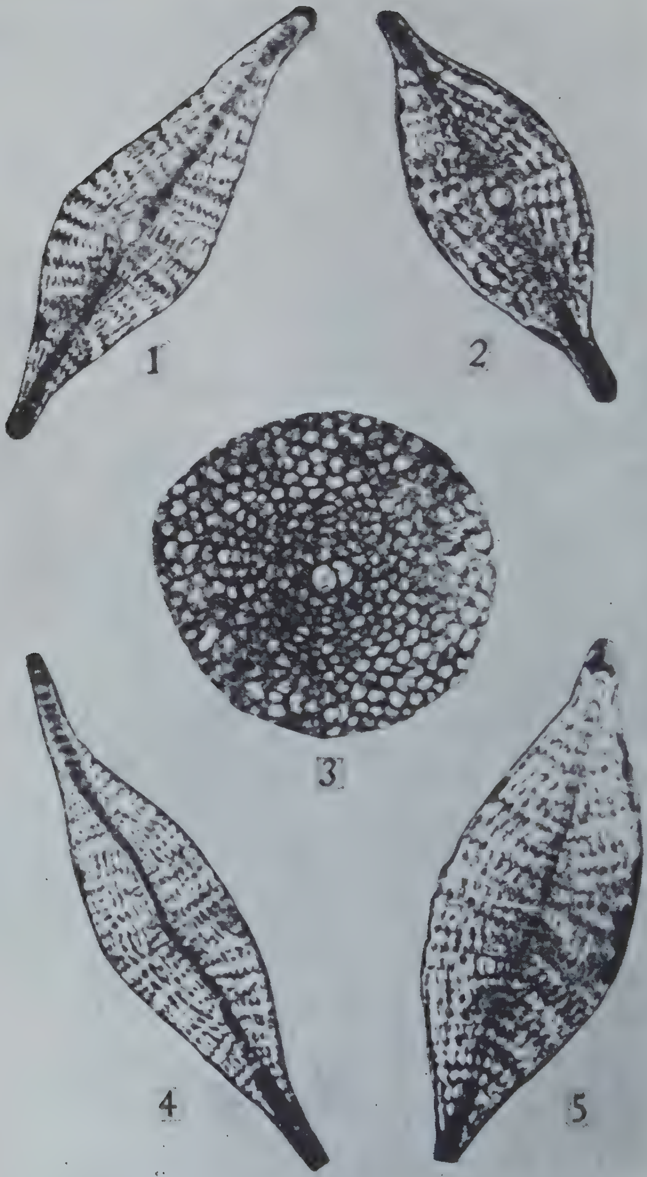
DISCUSSION.

When two species are present in a rock in both microspheric and megalospheric generations it is impossible to state which A and B forms should be associated. It becomes necessary, therefore, to put up four specific names, which Berry has done, and, having done so, it is not possible to state which microspheric form is directly connected with which megalospheric form. Berry states, however, that *L. carmani* and *L. brightoni* are the microspheric generations of *L. atascaderensis* and *L. columna* respectively, and gives very inadequate reasons for this. In making his species his statements are often definitely misleading.

He recognizes *L. brightoni* by its extreme thinness, and also states that *L. atascaderensis* and *L. carmani* are both extremely thin. He recognizes *L. atascaderensis* by the very thin, delicate walls of the equatorial chambers, but according to his measurements the walls in *L. brightoni* and *L. columna* are less than half as thick.

	Lepidocyclina atascaderensis Berry. A-form.	*L. columna* Berry. A-form.	*L. brightoni* Berry. B-form.	*L. carmeni* Berry. B-form.	*L. nuttalli* Berry. B-form.	*L. atascaderensis*, measurements from the Barrington Brown collection. A-form.	B-form.
Diameter	1·7 mm.	2 mm.	3 mm.	1·9 mm.	3·5 mm.	1·7–3·1 mm.	2·1–3·5 mm.
Thickness	0·75 mm.	0·45 mm.	0·5 mm.	0·67 mm.	1·17 mm.	0·4–0·86 mm.	0·46–1·06 mm.
Ratio D/T	2·2/1	4·4/1	6/1	2·8/1	3/1	2·5–4·5/1	2·6–6·3/1
Length of embryo . .	[1]195	210·6	—	—	—	185–240	—
Width of embryo . . .	132·6	136·5	—	—	—	130–167	—
Thickness of embryonic walls	11·7	15·6	—	—	—	11–18	—
Equatorial chambers (Rad. × Tang.)	78 × 86	65 × 84	58·5 × 90	46·8 × 58·5	78 × 109·2	60–75 × 65–80	65–70 × 70–85
Ht. of Equatorial layer (centre)	46·8	31·2	33·4	33	15·6	37	30
Ht. of Equatorial layer (Periph.)	66·3	46·8	83·5	89·7	100·2	75 up to 120	120
No. of tiers of lateral chambers	8–12	12	12	18	24	8–12	8–13
Height of lateral chambers .	27·3	15·6	24	23·4	19·5	18–30	18–28
Thickness of walls of lateral chambers . . .	11·7	15·6	8	11·7	15·6	15–22 up to 30	18–26

[1] All thicknesses in μ unless otherwise stated.



LEPIDOCYCLINA ATASCADERENSIS BERRY.

To face p. 351.]

He gives no reasons for distinguishing *L. columna* from *L. atascaderensis* and, except for the difference in the ratio of diameter to thickness, there seems to be no justification for differentiating the two.

L. nuttali is recognized by its large size and relatively great thickness, as well as by its finely papillate surface, but all the forms are said to be finely papillate, while it is only 0·5 mm. larger in diameter than his specimen of *L. brightoni*. Other measurements do not seem sufficiently different to make a new species.

A comparison of the five forms with the range of the redescribed form is given in the table on page 350.

EXPLANATION OF PLATE XVIII.

Lepidocyclina (Lepidocyclina) atascaderensis Berry.

FIG.			
1.—Megalospheric form.	Vertical section.	× 24.	Sedg. Mus. C. 539.
2.— „ „	Vertical section.	× 31·5.	Sedg. Mus. C. 539.
3.— „ „	Equatorial section.	× 31·5.	Sedg. Mus. C. 533.
4.—Microspheric form.	Vertical section.	× 24.	Sedg. Mus. C. 540.
5.— „ „	Vertical section.	× 31·5.	Sedg. Mus. C. 539.

ACKNOWLEDGMENT.

I have to thank Messrs. A. G. Brighton and W. A. Macfadyen, of the Sedgwick Museum, for their helpful criticism of this paper.

Graptolite Assemblages and the Doctrine of Trends.

By G. L. ELLES, Newnham College, Cambridge.

VIEWED in the light of the Doctrine of Trends some interesting facts seem to emerge from the consideration of the graptolites characteristic of some of the zones or successive assemblages of these fossils. These seem to illustrate so clearly one of the fundamental tenets of the doctrine—namely, the necessity for a large degree of independence in the different characters—that they may be worth placing on record.

The earliest graptolite known is *Dictyonema flabelliforme* or one of its varieties; the earliest variety in this country is var. *sociale* from just above the Peltura Beds, and the latest var. *anglica* from the Transition Beds of the Shineton Shales (1).[1] As is well known all these were pendent forms, and the first obvious changes that take place are either in the direction of stipe reduction alone, giving a *Bryograptus*, or a change in the position of growth plus some stipe reduction, resulting in *Clonograptus*, which may be regarded as a horizontally-growing *Bryograptus*. These then appear to constitute the first break away fron the parent stock, which may be regarded as taking place along TWO TREND LINES.

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[1] The numbers in parentheses refer to Bibliography at end of article.

Trend 1 : Stipe reduction.
Trend 2 : Change in position of growth.

It is highly significant and important that the bithecae so long considered to be one of the distinguishing features of the *Dendroidea* are still found in these forms of *Clonograptus and Bryograptus* (2) showing clearly that here is the bridge over the supposed gap between the two families, the *Graptoloidea* and the *Dendroidea.* Moreover recent work appears to have emphasized their possible connection still more closely. Everything suggests that the " bud " and " crossing canal " of the *Graptoloidea* are comparable with the " budding individual " of the *Dendroidea,* and both possess thecae or nourishing individuals. There remain therefore only the bithecae of the *Dendroidea* as distinctive and, in view of what Bulman has described (3) in regard to the behaviour of certain of these—i.e., that they may open into the thecae and that in the distal portions of the stipes of such a form as *Dictyonema falciferum* they are no longer visible on the outside as distinct structures—it is quite possible that they may have disappeared in similar fashion, but perhaps more speedily in the *Graptoloidea.* The occurrence of these bithecae then in the early *Bryograpti* and in *Clonograptus tenellus* is merely an indication of the relationship of the *Dendroidea* to the *Graptoloidea* and is only what might be reasonably expected if the *Graptoloidea* are derived from the early *Dendroidea.*

After the first break away from the parent stock development is amazingly rapid where change in position of growth has taken place—i.e., when trend 2 has been in operation—as if this had given a special stimulus to it, and the successive forms found depend entirely upon the relative dominance of one or other trend line. In one direction after the first indication of trend 2, trend 1 may assert itself and stipe reduction be carried out exclusively until from a graptolite with many stipes, one with a *horizontal uniserial stipe* has been produced. All stages along this line between *Dichograptus* and this *Azygograptus* are to be found in the Skiddaw Slates. Here trend 1 has completely outrun trend 2. This, however, by no means always happens, sometimes with the development of four horizontally-growing stipes (*Tetragraptus*) trend 1 is arrested, and trend 2 reasserts itself, giving first from the horizontal *Tetrag. quadribrachiatus* a slightly reclined form *T. amii,* then a more definitely reclined form *T. serra,* and finally the scandent *Tetragraptus, Phyllograptus angustifolius.* This is the goal of trend 2, so that at this stage trend 1 comes again to the fore and, accompanied by the minor trend of localization of thickening in the wall, probably gives origin to *Glossograptus.* This interpretation of the facts seems to offer a reasonable explanation why extensiform *Didymograpti* occur side by side with reclined *Tetragrapti* and scandent *Tetragrapti,* and also why *Glossograpti* make their appearance soon after *Phyllograptus* (4).

In yet other cases trend 1 operates throughout, and there is lacking the stimulus of change in position of growth, hence development lags, and stipe reduction is so slow that the two-stiped pendent *Didymograpti* are produced long after the two-stiped horizontal forms. Hence the tuning-fork *Didymograpti* do not appear till the middle of the horizon characterized as a whole by the extensiform *Didymograpti*, and do not become a dominant element in the fauna till the extensiform *Didymograpti* have almost disappeared.

In the late horizontally growing *Didymograpti* a third trend line (trend 3) may supervene and give us the first stages of cell elaboration with the development of the sigmoid cell. This may take place in the Upper Arenig or Lower Llanvirn; with this development trends 1 and 2 are arrested, so that the earliest *Leptograptus* is horizontal; this cell elaboration having been attained, trend 3 is temporarily arrested and trend 2 reasserts itself, so that the *Leptograpti* become reflexed and reclined; then may follow a reassertion of trend 3 giving us eventually the type of *Dicellograptus* with its elaborately twisted cell (type *a*); this is the acme of development of trend 3; this greatest development of cell elaboration may, however, never be attained, the thecal elaboration being arrested earlier so that there is formed a cell of simpler type, in some respects intermediate between a *Leptograptus* on the one hand, and a complicated-celled *Dicellograptus* on the other; these are often referred to as the "simple-celled *Dicellograpti* type *b*," in them also there is a reassertion of trend 2 so that there may be developed successively corresponding *Dicranograpti* and *Climacograpti*. These appear to be of commoner occurrence. With the attainment of these *Climacograptus* forms trend 2 has attained its goal, all that remains to be accomplished is the further stipe reduction to uniserial forms, i.e. the reassertion of trend 1. Thus is attained the development of those *Monograpti* with cells like *Leptograptus* (*M. atavus, incommodus, and sandersoni*) or *Dicellograptus* types *a* and *b* (*M. vomerinus, M. argutus*).

The characteristic feature of the greatest number of the Llandeilo graptolites is thus this sigmoid cell, and the association of *Leptograptus*, *Dicellograptus*, and *Dicranograptus* with cells in different degrees of elaboration again finds a reasonable explanation in the application of the Doctrine of Trends. It should also be noted that *Climacograptus* is in its origin quite distinct from *Diplograptus*, which it only resembles in having reached a similar evolutional stage.

Some of the large *Orthograpti* have so close a resemblance to some *Phyllograpti* that they may well have arisen from such forms by the reassertion of trend 1 after that stage was reached. Field evidence is however incomplete at present on this point and it can only be suggested as a theoretical possibility. After the development of these *Orthograpti* the general trend followed is clearly trend 1 through different *Dimorphograpti* to various *Monograpti*.

On this line there is no suggestion of trend 3 till the goal of trends

1 and 2 has been attained. Then follows what has been termed the second episode of cell elaboration, but it is the first on this main line of development.

It is therefore not in the least anomalous that the *Dimorphograpti* should occur side by side with the earliest *Monograpti* of the other line (*Leptograptus* line), and the big *Orthog. vesiculosus* which also occurs with them is the last representative of the big *Orthograpti* from which the greatest number of *Monograpti* are directly or indirectly derived. The Caradocian graptolite assemblages are all to be interpreted as different stages of development on the two main lines. There is some retrogression on the *Leptograptus* line at the top of the Ashgillian, and notable retrogression on the *Orthograptus* line throughout the greater part of the Salopian so that the one and only successful line of cell elaboration returns to its starting point and differences in the form of the rhabdosome alone remain to distinguish the Ludlow simple-celled *Monograpti* from those of early Valentian time.

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2. STUBBLEFIELD, 1929. "Notes on some Early British Graptolites," GEOL. MAG., LXVI, 780, 268.
3. BULMAN, 1928. Loc. cit., pt. ii.
4. ELLES, 1925. "The Characteristic Assemblages of the Graptolite Zones of the British Isles," GEOL. MAG., LXII, 337.

Some New Ordovician Species of *Conularia* from Girvan.

By F. R. COWPER REED, Sc.D., F.G.S.

(PLATE XIX.)

AMONGST Mr. James L. Begg's recent collections of fossils from the Upper Bala (Starfish Bed) of Thraive Glen, Girvan, there are several specimens of the genus *Conularia*, one of which has the apertural lobes well preserved, which is apparently unique in British Ordovician examples of this genus, and another shows internal structures of peculiar interest. A third new species is closely related to the one which Miss Slater named *C. hispida*, and a fourth is allied to *C. plicata* Slater. In Miss Slater's monograph[1] on the British Conulariae, published in 1907, the following four species were described from the Upper Bala of Thraive Glen: *C.* cf. *aspersa* Lindstr., which is typically a Wenlock species; *C. hispida* Slater, which was also founded on Wenlock specimens; and *C. plicata* Slater and *C. planiseptata* Slater, which were recorded only from Thraive Glen.

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[1] Slater, *British Conulariae* (Palaeont. Soc.), 1907.

Conularia slateri sp. nov.

Pl. XIX, Figs. 2, 2*a–c*.

Shell large, pyramidal, straight, rectangular, with only the opposite faces of equal size, the dorsal and ventral faces being wider than the lateral; angles of shell slightly prominent; faces flattened or very slightly convex, with a narrow low median longitudinal ridge forming the segmental line and corresponding to a low internal ridge or septum. Apical angle 20°–25°. Apertural end truncated at right-angles to axis, with rounded edges at junction with faces, and completely closed by two pairs of flat triangular lobes nearly or quite meeting in the centre, the opposite lobes of equal size and shape, the lateral ones being equilateral triangles, and all bisected by continuations of the segmental lines of the faces. Surface of faces ornamented by very numerous closely-set fine transverse lines, about 35–40 in 5 mm., bearing minute subquadrate or rounded nodules, which are also arranged in longitudinal series so as to produce a fine longitudinal striation and cancellation of the surface; on the apertural lobes some of the transverse lines are thicker and coarser than the rest, and the nodulation and longitudinal striation are not apparent; all the transverse lines on the faces and lobes cross the segmental line without interruption or angulation.

Dimensions:—

Length of specimen (tip broken)	.	*c.* 73 mm.
Estimated length of perfect shell	.	*c.* 100 „
Dorso-ventral diameter at aperture	.	22 „
Transverse diameter at aperture	.	32 „

Horizon and Locality.—Starfish Bed, Thraive Glen, Girvan.

Remarks.—The one specimen of this new species is somewhat crushed, and the apex is missing and the ornamentation is only preserved in a few places, but otherwise it is perfect. The dorsal and adjoining lateral faces are crushed in, and on each side of the segmental line of the dorsal face there is a trace of a fine accessory longitudinal line at about a third the distance from the centre to the angle, but whether this is due to cracks in the shell or indicates a true additional pair of thin septa is doubtful. The species which Miss Slater [1] described as *C.* cf. *aspersa* Lindstr. bears a close resemblance, but *C. aspersa* Lindstr.[2] is typically a Silurian species and occurs in the Pterygotus Shales of Wisby. Wiman [3] has figured an example from the Borkholm beds of the Baltic. The ornamentation of *C. aspersa* and of *C. imperialis* Barr [4] much resembles that of our species, and it is probable that *C. curta* Sandb. as described and figured by Holm [5] is also allied.

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[1] Slater, op. cit., 21, pl. i, fig. 13, 14.

[2] Lindström, *Svensk. Vet. Akad. Handl.*, Bd. xix, No. 6, 1881, 46, pl. vii, figs. 1–3; Holm, *Sver. Geol. Undersökn*, Ser. 6, No. 112, 1893, 134, t. vi, figs. 43–6.

[3] Wiman, *Bull. Geol. Instit. Upsala*, No. 10, v, pt. ii, 1900, 182, t. vii, figs. 13–16.

[4] Bouček, *Palaeont. Bohême*, xi, 1928, 73, pl. iii, figs. 1–5, text-fig. 5.

[5] Holm, op. cit., 1893, 131, t. iv, figs. 45–8.

Conularia mirifica sp. nov.

Pl. XIX, Figs. 1, 1*a*, *b*.

Shell pyramidal, rectangular with the opposite faces only of equal size, the dorsal and ventral being wider than the lateral. Apical angle, 20°–25°. Angles of shell slightly prominent and having a narrow longitudinal groove along them; faces of shell flat or slightly concave, with a slightly raised median segmental line corresponding to an internal low narrow rounded ridge which at about half the length of the shell gradually thickens so as to become near the apex a stout cylindrical rod attached to the wall and composed of concentric shelly layers, the rods of the four faces becoming nearly in contact and almost filling up the entire apical cavity of the shell, the small median area having a small central pit at the transverse diaphragm at which the actual apical end is broken off. Apertural end not preserved. Ornamentation composed of very faint minutely granulated transverse lines crossing the segmental line at right-angles.

Dimensions :—

Length of specimen	*c.*	35 mm.
Dorso-ventral diameter . . .	*c.*	11 „
Transverse diameter	*c.*	15 „

Horizon and Locality.—Starfish Bed, Thraive Glen, Girvan.

Remarks.—There is only one specimen of this curious shell, but it shows the internal structure clearly, though the apertural end is broken and obscured by tough matrix; the apex is also missing, but has been broken off at the strongly arched transverse diaphragm. The peculiar four internal rod-like structures into which the longitudinal septa of the segmental lines develop apically are similar to those in *Palænigma wrangeli* (Schmidt),[1] which occurs in the Lyckholm stage of the Baltic Ordovician, but they have not been previously found in any species of *Conularia*, though Lindström [2] suggested that the Russian fossil was connected with *Conularia* by such thick shelled species as *C. fecunda* Barr.[3] Walcott [4] believed that *Palænigma* was allied to his Cambrian genus *Matthevia* [5] as well as to *Conularia*, but we may doubt this relationship. We may observe that the summit view of the apical end of *P. wrangeli* given by Schmidt [6] shows a median pit as in our specimen, and the summit view given by Walcott (op. cit.) shows the concentric structure and regular quadrangular arrangement of the internal rods, but no median pit. Miss Slater [7] mentions and figures a similar transverse apical diaphragm in *C. planiseptata* and also a probable median siphuncle which may correspond with this pit. In *C. anomala* Barr.[1] and *C. consobrina* Barr.[2] the transverse diaphragm is well developed.

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[1] Schmidt, *Mem. Acad. Imper. Sc. St. Petersb.* Ser. vii, xxi, No. 11, 1874, 42, t. iv, figs. 3–8; Holm, op. cit., 1893, 141.

[2] Lindström, op. cit. 41.

[3] Bouček, op. cit., 66, pl. i, figs. 5–10, text-fig. 3.

[4] Walcott, *Bull. XXX U.S. Geol. Surv.* 1886, 223, pl. xxxiii, figs. 2, 2*a*–*c*.

[5] Id. *Smithson Misc. Coll.*, lvii, No. 9, 1912, 265, pl. xlii, figs. 1–15.

[6] Schmidt, op. cit., t. iv, fig. 3c.

[7] Slater, op. cit., 35, pl. v, figs. 8, 9.

Conularia cunctata sp. nov.

Pl. XIX, Figs. 3, 3*a*, *b*.

Shell large, elongated-pyramidal, tapering slowly at about 10°–15° to apex, rectangular, with the opposite faces only of equal width, the dorsal and ventral faces being wider than the lateral; angles of shell folded in, with rounded edges; faces flat, without any definite segmental line, but ornamented by narrow subangular rather widely separated transverse ridges, 23–5 in 10 mm., which are obtusely angulated in the median line of the lateral faces, but more widely angulated on the dorsal and ventral faces and become merely widely arched towards the apical and apertural ends of the shell; the transverse ridges are crossed by short rather thick closely placed longitudinal lines; the interspaces are three to four times as wide as the ridges and are crossed by finer longitudinal lines, which in places become almost obsolete sc that the interspaces appear smooth.

Dimensions.—

Length of specimen	*c.* 82 mm.
Estimated length when perfect . .	*c.* 100 ,,
Dorso-ventral diameter . . .	18 ,,
Transverse diameter	21 ,,

Horizon and Locality.—Starfish Bed, Thraive Glen, Girvan.

Remarks.—There is one nearly complete example of this species, but the apertural and apical ends are broken. It is closely allied to *C. hispida* Slater,[3] which was founded on a Wenlock species, but Miss Slater referred certain specimens from Thraive Glen also to it, and they are probably identical with the species above described. It seems to differ from the form described by Miss Slater, for the latter is stated to have eight to twenty-four ridges in 5 mm., and to have the ridges studded with small pear-shaped tubercles, which are only prolonged half across the interspaces.

Conularia asteroidea sp. nov.

Pl. XIX, Figs. 4, 4*a*.

A crushed fragment measuring about 11 mm. in length, consisting of the upper portion of two flattened-out adjacent faces of a species of *Conularia* with infolded angles and rather rapid tapering (No. B.G. 2002), shows certain characters in its ornamentation which distinguish it from its close allies, *C. crassa* Slater[1] and *C. planiseptata* Slater.[2] The faces of our specimen are traversed by straight transverse ridges obtusely angulated in the middle and bearing a series of small hollow equidistant rather closely placed tubercles of an oval shape being elongated along the ridges. There are 12–14 ridges in 5 mm. and the interspaces which are deep and concave and about twice as wide are crossed by rather thick low rounded equidistant bars situated further apart than the ridges so as to form transversely oblong cancellae; these bars do not regularly alternate in successive interspaces nor do they correspond precisely with the tubercles.

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[1] Bouček, op. cit., 76, pl. iii, figs. 12, 13.

[2] Ibid., 78, pl. iv, figs., 8, 9.

[3] Slater, op. cit., 28, pl. iii, figs. 9*a*, *b*, 10 (Wenlock Limestone); fig. 11 (Thraive Glen).

C. planiseptata has the bars in the interspaces forming square cancellae and the tubercles on the ridges are round and not oval. *C. crassa* Slater, however, has the tubercles as in our species; *C. plicata* Slater,[3] which also occurs in Mr. Begg's collection from Thraive Glen, has smaller tubercles and only 9–12 ridges in 5 mm., while the crossbars in the interspaces are more numerous, closer, and weaker. *C. pulchella* Lindstr.[4] and *C. telum* Holm[5] are allied to our new species.

EXPLANATION OF PLATE XIX.

Fig.

1. —*Conularia mirifica* sp. nov. Dorsal face, showing linear cavity left by internal rod of segmental line. × 2.

1*a*.—*C. mirifica* sp. nov. Lateral face, showing similar features. × 2.

1*b*.—*C. mirifica* sp. nov. Apical view, showing the four rods and median pit on the transverse diaphragm. × 2.

2. —*C. slateri* sp. nov. Dorsal and left lateral faces. Nat. size.

2*a*.—*C. slateri* sp. nov. Upper portion (crushed) of ventral and right lateral faces, showing narrow internal median rod-like septum of segmental line. × 1½.

2*b*.—*C. slateri* sp. nov. Portion of surface of face, showing ornamentation. × 12.

2*c*.—*C. slateri* sp. nov. Apertural end of same specimen showing covering flaps. Nat. size.

3. —*C. cunctata* sp. nov. Dorsal and left lateral faces. Nat. size.

3*a*.—*C. cunctata* sp. nov. Portion of surface, showing ornamentation. × 12.

3*b*.—*C. cunctata* sp. nov. Transverse section of specimen. Nat size.

4. —*C. asteroidea* sp. nov. Upper portion of two faces (crushed). × 2.

4*a*.—*C. asteroidea* sp. nov. Portion of surface, showing ornamentation. × 12.

Note.—All the above specimens are from the Upper Bala (Starfish Bed), Thraive Glen, Girvan, and are in Mr. James L. Begg's collection.

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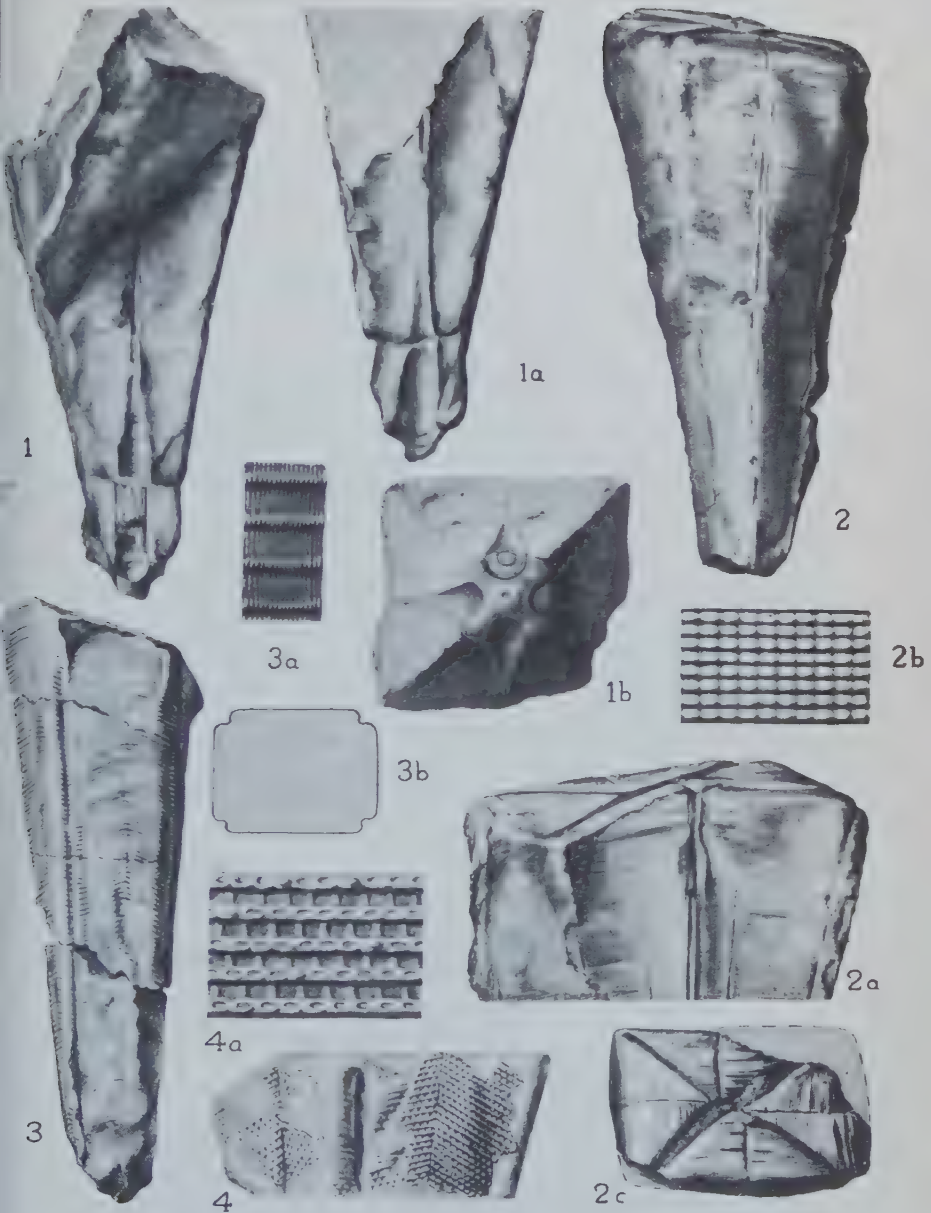
[1] Slater, op. cit., 32, pl. iv, figs. 4–6.
[2] Ibid., 35, pl. v, figs. 1, 2.
[3] Ibid., 31, pl. iv, figs. 2, 3.
[4] Holm, op. cit., 139, t. iv, figs. 6–11.
[5] Ibid., 143, t. iv, figs. 16–20.



E. T. Talbot, del.

NEW ORDOVICIAN SPECIES OF *CONULARIA*.

Richmondian Trilobites from Akpatok Island.

By IAN COX, B.A., Sedgwick Museum, Cambridge.

[*Contributions to the Geology of Akpatok Island, No. 3.*]

(PLATE XX.)

I. INTRODUCTION.

THE Trilobites, which include one new species, here described were collected by the writer from Akpatok Island [1] in Ungava Bay while on the Oxford Hudson Straits Expedition in 1931. The single species of graptolite found there has already been described [2]; in addition to the trilobites, there are brachiopods, corals, crinoids, gasteropods, cephalopods, and ostracods, which still await identification. The following species of trilobites are here recorded: *Isotelus iowensis* Owen, *Megalaspis beckeri* Slocom, *Illaenus eucentrus* Troedsson, *Illaenus groenlandicus* Troedsson, *Bumastus* sp., *Calymene* cf. *fayettensis* Slocom, *Calymene* cf. *meeki* Foerste, *Encrinurus* sp., *Ceraurus horridus* Troedsson, *Ceraurus tuberosus* Troedsson, *Ceraurinus icarus* (Billings), *Ceraurinus daedalus* sp. nov., *Pterygometopus fredricki* Slocom.

II. LITHOLOGY.

Since so much of the island is covered deep in scree and the sea-cliffs are inaccessible, fossils were collected principally from stream sections and the wave cut platform on the shore. The large stream [3] reaching the sea just north of the south-east point affords the best section, and it was chiefly from here that the fossils were recovered. Their relative heights of occurrence are accurately known from field notes but the estimation of feet above sea-level, made at the time of collection, can only be approximate. The section is as follows; no unconformity was observed in the series:—

SECTION ON EAST OF AKPATOK ISLAND.

Approximate height M.S.L. in feet.	
850 +	Weathered limestone with badly preserved fossils (no trilobites).
700–850	Barren limestone weathering into flags.
473–700	Banded limestones (barren on the east of the island).
470–473	*Graptolite Band.* Chocolate-coloured limestone with *Climacograptus inuiti* Cox.
450–470	Massive yellow limestone.
450	"*Pink Band.*"—Thin, very fossiliferous band of limestone with trilobites and brachiopods preserved with pink shells. Many crinoids. *Dinorthis proavita* W. & S.

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[1] For a general account of Akpatok Island see H. M. Clutterbuck, *Geographical Journal*, lxxx, 1932, 211 et seq.

[2] Ian Cox, GEOL. MAG., LXX, No. 823, 1933, 1 et seq.

[3] This stream has been described by the present writer in the GEOL. MAG., LXX, No. 824, 1933, 70 et seq.

Approximate height M.S.L. in feet.	
0–450	Massive yellow limestone akin to calcite mudstone with gasteropods and cephalopods. Thin (4–6 in.) bands of shelly limestone rich in brachiopods and corals occur at intervals. At about 380 feet a band of limestone nodules with chalky surface occurs in the massive beds. *Rhynchotrema Capax* (Con.) occurs throughout the thickness.

III. Description of Species.

All the specimens here described are preserved in the Sedgwick Museum, Cambridge, to the catalogue of which numbers in brackets refer.

ASAPHIDAE Burmeister.

Genus Isotelus de Kay.

Isotelus iowensis Owen.

Owen, D. D., *Rep. of a Geol. Surv., Wisconsin, Iowa, and Minnesota*, 1852, 577, tab. 2*a*, figs. 1–7.

Represented by a cast of the pygidium.

Pygidium sub-triangular, rounded; laterally convex; length, 37 mm.; width, 40 mm. Axial lobe very faintly defined except at the termination; tapers fairly abruptly from the anterior for a short distance and then gently to the rounded termination. Annulation exceedingly faint. Pleural lobes convex; marginal border slightly concave and of constant width; segmentation extremely indistinct.

According to Raymond,[1] the adult pygidium of *I. iowensis* can be distinguished from *I. gigas* by its rounded posterior end, and from *I. maximus* by the ratio of length to breadth being above ·65. By these criteria the Akpatok pygidium can only belong to the species *I. iowensis*. However, it is somewhat narrower than any of those figured by Raymond [2] or Clarke [3] and, indeed, is exceedingly similar in proportion to a specimen of *Megalaspis centaurus* var. *rudis* Ang. figured by Schmidt,[4] although it seems to belong to the genus *Isotelus*.

I. iowensis is a Richmondian form and has been recorded from the Lower Maquoketa beds of Turkey River, Clermont, and Elgin, Iowa.[5] It is also recorded from the Cape Calhoun beds of north-west Greenland.[6] The Akpatok specimen came from sea-level. [A 4769.]

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[1] P. E. Raymond, *Bull. Mus. Comp. Zool. Harvard*, lviii, No. 5, 1914, 259.

[2] Ibid., pl. ii, fig. 6; pl. iii, figs. 1 and 2.

[3] J. M. Clarke, *Final Rep. Geol. and Nat. Hist. Surv. Minnesota*, iii, 1894, fig. 5. This is called *I. maximus* Locke, but Raymond regards it as a typical *I. iowensis*.

[4] Fr. Schmidt, *Mém. de l'Acad. Imp. des Sciences de St.-Pétersbourg*, viii^{e} série, xix, No. 10, Taf. viii, fig. 6.

[5] A. W. Slocom, *Iowa Geol. Surv. XXVth Ann. Rep.*, 1914, 196.

[6] G. F. Troedsson, *Med. om Grønland*, lxxii, 1928, 29.

Genus MEGALASPIS Angelin.

Megalaspis beckeri Slocom.

Pl. XX, Fig. 18.

Slocom, A. W., *Field Mus. Nat. Hist.*, Geol., Ser. iv., 50,[1] pl. xiv, fig. 5.

Represented in the Akpatok Collection by two pygidia. These are not well preserved in the axial region.

Pygidium triangular in outline; slightly produced posteriorly. Axial lobe convex; not strongly defined; tapering rapidly at first and then gently; terminating bluntly in front of and near to the marginal border. Axial furrows very shallow. Pleural lobes very gently convex for the greater part of width, but curve down abruptly at the margins; marginal border approximates to the horizontal at the posterior end only; segmentation very faintly defined anteriorly and apparently not visible posteriorly; facets pronounced; concave; extending for about one-half the width of the lobe. Surface appears to be finely punctate.

Slocom's figure [2] is of a specimen with a somewhat damaged pygidium. This may account for the Akpatok specimens agreeing with the type in all characters but the posterior production, a feature seen in other species such as *M. acuticauda* Ang. or *M. heros* Dalm., with which they have far less in common in other respects. However, it is a character liable to variation with age and even the two Akpatok pygidia are not produced to exactly the same extent.

Slocom's type is from the Lower Maquoketa beds at Clermont, which are Richmondian. The Akpatok examples come from the south-west plateau at 650 feet. [A 4770–1.]

ILLAENIDAE Corda.

Genus ILLAENUS Dalman.

Illaenus eucentrus Troedsson.

Troedsson, G. F., *Med. om Grønland*, lxxii, 1928, 38, pl. 14, fig. 1–4.

This species is represented by a small specimen not very well preserved. It conforms with Troedsson's description except that it is punctate rather than coarsely punctate.

I. eucentrus was described from the Cape Colhoun beds of North-West Greenland. The Akpatok specimen was found at 450 feet. [A 4760.]

Illaenus groenlandicus Troedsson.

Pl. XX, Fig. 4–6.

Troedsson, G. F., *Med. om Grønland*, lxxii, 1928, 36–8, pl. xiii. figs. 8–18.

This species is abundantly represented by pygidia and cephala on Akpatok Island, especially in the lowest beds exposed. The forms collected agree entirely with Troedsson's description, which there is no necessity to repeat here.

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[1] This paper was reprinted in *Iowa Geol. Surv. XXVth Ann. Rep.*, 1914, Des Moines, 1916, with no change, so far as the references here given are concerned, except in pagination and plate numbers.

[2] A. W. Slocom, *Iowa Geol. Surv. XXVth Ann. Rep.*, 1914, pl. xv, fig. 5.

I. groenlandicus types came from the Cape Colhoun beds of North-West Greenland. "The fact that the closely allied species have been found in the Black River and Trenton of North America, and in equivalent beds of the Baltic region, might indicate Mohawkian age of this species." [1] The similarity of Black River and Richmondian faunas has been considered by Foerste,[2] who writes: "The fact that many Black River and Trenton genera recur in the Richmond, but not in the Eden or Maysville formations has been known for many years . . . In a similar manner, certain species well known in the Richmond find their nearest representatives in the Black River or Trenton formations" (and here he discusses a certain number). Thus it does not seem irregular that a Richmondian form should have its nearest relations in the Trenton and Black River formation, nor is it necessary on this score to consider *I. groenlandicus* of Mohawkian age.

Ulrich wrote of recurrent faunas: "The Palaeozoic rocks of America afford many instances of species that entered periodically into the faunal history of the interior basins. These species . . . were of vigorous stocks and generally very prolific. On account of their vigor they existed, with a minimum of modification, through a longer period of time than more sensitive species. . . . *Plectambonites sericeus* is represented by barely distinguishable variants in the Stones River, the late Black River, in late Trenton, in the Eden, and finally by two mutations in the Richmond" [3] and of the Maquoketa Shale and Sylvan Shale (both Richmond) faunas. "The species are nearly all so closely allied to well-known Utica Shale fossils that unless they are very thoroughly compared the distinctions may easily be overlooked. However . . . the Sylvan and Maquoketa Shales overlie unquestionably Richmond faunas." [4]

Work in progress on the brachiopods of the lowest stratum on Akpatok Island indicates a possibility of a recurrence of earlier types here also.

The Akpatok specimens were found from sea-level up to a height of 400 feet, and are associated with Richmondian forms. [A 4761–7.]

Bumastus Murchison.

A central portion of cephalon and an imperfect pygidium referable to this genus were obtained. They are not complete enough to make specific identification possible nor can they be matched with species recorded by Troedsson from beds on North-West Greenland containing a fauna similar to that of Akpatok Island. The specimens came from a height of 450 feet in the limestone. [A 4791–2.]

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[1] Troedsson, op. cit., 38.

[2] A. F. Foerste, "The Ordovician Faunas of Ontario and Quebec," *Mem. Geol. Surv. Canada*, 138, 1924, 43 et seq.

[3] E. O. Ulrich, "Revision of the Palaeozoic Systems," *Bull. Geol. Soc. Amer.*, 1911, xxii, 298.

[4] Ibid., 300.

CALYMENIDAE Milne-Edwards.

Genus CALYMENE Brogniart.

Calymene cf. *fayettensis* Slocom.

Pl. XX, Fig. 1.

Calymene fayettensis Slocom, 1913, *Field Mus. Nat. Hist.* Geol., Ser. IV, 67, pl. XVI, figs. 8–9.

This species is probably represented by a well-preserved cephalon lacking free cheeks and with genal angles obscured.

The cephalon fully agrees with Slocom's description, but on account of the obscurity of his figures and because the genal angles of the Akpatok specimen are hidden a closer comparison cannot be made. Under the circumstances the form is distinguished from *C. retrorsa minuens* Foerste by its papillose surface and a less reflexed anterior border.

The type of *C. fayettensis* is from the Lower Maquoketa beds. The Akpatok specimen was found at 640 feet on the south-west of the island. [A. 4786.]

Calymene cf. *meeki* Foerste.

Foerste, A. F., *Bull. Sci. Lab.*, Denison Univ., XV, 86, pl. iii, fig. 18.

Represented in the Akpatok collection by the major portion of a glabella with left fixed cheek and anterior border. Close identification is impossible on account of the genal angle being wanting and the glabella being somewhat flattened. The cephalon is smaller than those figured by Foerste. The form is compared with *C. meeki* rather than *C. meeki retrorsa* on account of the relative width of the anterior border. *C. meeki* is characteristic of the Maysville member of the Richmondian. The Akpatok specimen is from a height of 450 feet. [A. 4787.]

An enrolled specimen and a pygidium, both preserved as casts, were also recovered, and although it seems probable that they belong to the *C. meeki* group, they are insufficiently clear to permit further identification. [A 4788.]

ENCRINURIDAE Angelin.

Genus ENCRINURUS Emmrich.

Encrinurus sp.

Pl. XX, Fig. 3.

Represented by a well-preserved pygidium. Subpentagonal in outline; breadth slightly greater than length; axis one-third the width of the pygidium at the anterior end; convex; constantly tapering; ends on a level with the ultimate pleurae; with at least sixteen segments; ring furrows continuous in the anterior three segments but posterior to this are effaced along the middle of the xis and become fainter and shorter posteriorly. Pleural lobes of x distinct segments; convex; with a sudden steepening on a line joining the centre of length of all the pleura. Pleura flattened with obtuse tips; the anterior four end free but the posterior two pairs are fused at their ends and lie higher than the others. Inter-pleural furrows strongly impressed; the last two pairs do not reach the margin. Anterior pair of pleura with a short furrow; strongly geniculated so that the lateral halves of their length lie parallel to the axis; second pair with slight geniculation; third pair curved; and sixth pair straight and lying parallel to the axis. There is no trace of ornament. The lack of ornament and the small number of continuous axial furrows might be due to rolling of the specimen before fossilization; this would first affect the central portion of the axis and render the fainter furrows discontinuous in this region.

This pygidium is not unlike the Rhiwlas *E. sexcostatus* Salter [1] (especially Salter's fig. 3, pl. iv). But that form is larger, has stronger furrows; its pygidium is "wider by one-third than its length", and the geniculation is less strong. There are also twenty annulations in that form. Troedsson's figures of "*E. rarus* Walcott (?)" [2] are also similar, but differ in being longer than broad, having a less pronounced geniculation; the last two pairs of interpleural furrows continue to the margin and a greater number of axial furrows are continuous (but see above). Troedsson says that the axial segments vary in number up to twenty, but the figure shows fifteen to sixteen as in the Akpatok specimen. Slocom's *E. pernodosus* [3] has the same proportion of breadth to length, but its pleural lobes have "seven distinct ribs", and "a prominent knob-like distal end". His figures are too indistinct to permit further comparison.

The Akpatok specimen came from a height of 400 feet. [A 4768.]

CHEIRURIDAE Salter.

Genus CERAURUS Green (Raymond and Barton).

Ceraurus horridus Troedsson.

Pl. XX, Fig. 2.

Troedsson, G. F., *Med. om Grønland*, lxxii, 1928, 65, pl. xvii, figs. 1–9.

This species is represented by a single cast of glabella with the greater part of the fixed cheeks.

Description of cast of Cranidium.—Glabella strongly convex longitudinally and depressed convex transversely; length anterior to level of the occipital furrow less than the maximum breadth; anterior slope very steep. Axial furrows strongly impressed;

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[1] *Mem. Geol. Surv.*, "Organic Remains," Decade 7, 1–5, pl. iv, figs. 1–12, 1853.

[2] G. F. Troedsson, *Med. om Grønland*, lxxii, 59–61, pl. xvi, figs. 8 and 9, 1928.

[3] A. W. Slocom, op. cit., 211.

diverge forward but in front of the first pair of lateral lobes curve inward, gently rounding the anterior lobe. Anterior lobe one-third the length of the glabella. Glabellar furrows straight, transverse. The first pair of furrows one-fifth the width of the glabella; deep where they join the axial furrows but rapidly effaced. Second pair of furrows shallower and do not deepen toward the axial furrows. Third pair of furrows wider and deeper than the second and terminate in a pit; a very shallow furrow runs backward longitudinally from here across the base of the third glabellar lobe to join the occipital furrow. Occipital furrow discontinuous, being represented by two furrows one-quarter the width of the glabella in that latitude. The lateral lobes meet the axial furrows very steeply; decrease in size backward; the basal pair being depressed and considerably isolated. The glabella bears strong tubercles with which the anterior lobe is abundantly covered, but posteriorly the tubercles lie on two lines, one of which runs on to the first and the other on to the second lateral lobes. No tuberculation is visible posterior to the third lateral furrows.

The fixed cheeks appear to be broad, slope downward laterally and steeply forward; tuberculate. Posterior furrows deep; posterior borders sparsely tuberculate. Cheeks strongly elevated near the eye lobes. Eye lobes very prominent, directed forward outward and upward. A strong ridge runs from this lobe in the direction of the first lateral furrow and anterior to it the cheek slopes abruptly downward.

Since it is preserved as a cast this specimen shows slight variation from that described and figured by Troedsson. The main differences are in the accentuation of the major furrows with attendant exaggeration in the isolation of the lateral lobes, and the obscuring of finer tuberculation.

The type of *C. horridus* came from the Cape Colhoun beds of North-West Greenland and has "been found on slabs associated with true Richmondian forms".[1] The Akpatok specimen was found at a height of 350 feet. [A 4785.]

Ceraurus tuberosus Troedsson.

Pl. XX, Figs. 16–17.

Troedsson, G. F., *Med. om Grønland*, lxxii, 1928, 7, pl. xvii, fig. 13; pl. xviii, figs. 1–9.

"*Ceraurus tuberosus* is distinguished, on account of its coarsely granulated, expanded, and dilated glabella, from the congeneric species with small basal glabellar lobes" (Troedsson, p. 72).

This species is represented in the Akpatok collection by four imperfect cranidia and two lateral portions of the fixed cheeks with genal spines. Examination of metatypes of the species, made possible by the courtesy of the University of Copenhagen, left no doubt as to the correctness of identification. The tuberculation of the fixed cheeks of the species seems far from constant; Troedsson's figs. 2–5, pl. xviii, exemplify this. In the Akpatok specimens, there is on the posterior margin of the fixed cheek, a short distance inward from the base of the genal spine, a single prominent tubercle. This constitutes a slight difference from *C. tuberosus* as figured, for there two smaller tubercles are visible; but since these single tubercles on the Akpatok specimens can be seen to have been formed by the fusion of two or three smaller ones, and because the Greenland examples exhibit variation in this respect, the difference would seem to have little significance. The outer surfaces of the genal spines of the Akpatok specimens are shagreened with closely-set and very small sharp papillae. On the more posterior and lateral surfaces of the fixed cheeks obtuse pits are more obvious than the tuberculation.

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[1] Troedsson, op. cit., 149.

C. tuberosus was described from the Cape Colhoun beds of North-West Greenland, and has "been found in slabs associated with true Richmondian forms".[1] The Akpatok examples were recovered from heights between 350 and 450 feet. [A 4755–9.]

Genus CERAURINUS Barton.

Ceraurinus icarus (Billings) Slocom.

Pl. XX, Figs. 7–9.

Billings, E., *Can. Nat. and Geol.*, v, 1860, 67, fig. 11.
Slocom, A. W., *Iowa Geol. Surv. XXVth Ann. Rep.*, 1914, 227, pl. xviii, figs. 6–9.

Represented by eight cephala without free cheeks and one cast of a pygidium. The Akpatok examples are constantly much smaller than those recorded from elsewhere.

Cephalon sub-semicircular in outline; slightly flattened anteriorly. The length along the median line being about one-half the width at the level of the occipital furrow. Posterior margin straight. Genal spines one-third the length of the cephalon along the median line; directed posteriorly and slightly outward.

Glabella depressed convex, subquadrate, length anterior to the occipital furrow slightly more than the width; very obtusely rounded in front; anterior slope gentle; axial furrows strongly impressed; straight; slightly diverging anteriorly. The glabella occupies at its posterior margin one-third or slightly less of the entire width of the cephalon. Frontal lobes about one-third the entire length of the glabella. Anterior and median lateral glabellar furrows one-third the width of the glabella, curving faintly posteriorly; anterior and median lobes subrectangular and equal in size. Third lateral glabellar furrows deeper and slightly shorter than the anterior and median furrows, and connected by a short deep pseudo-axial furrow to the occipital furrow, which is deep and arches strongly forward, but is straight in its median third. Basal lobes strongly isolated, subrectangular with rounded corners but may taper slightly inward. Occipital ring broad in middle, but narrows to the sides. Anterior border of the cephalon very gently rounded and narrow in front of the glabella.

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[1] Troedsson, op. cit., 149.

Cheeks sloping downward laterally and (to a less extent) anteriorly; gently convex. Posterior furrows deep and wide, meeting the lateral furrows, which are shallow, anterior to the genal spines. Lateral marginal borders slightly concave on account of the shallow lateral furrows. Posterior borders raised and grow flatter and slightly broader towards the margins. Eyes moderate, situated opposite the second glabellar furrows. Palpebral lobes moderate; palpebral furrows distinct. Anterior branches of the facial sutures converge moderately in front of the eyes and turn inward with an obtuse curve to cut the anterior margin in front of the glabella one-quarter of its width inward from a line projected forward from the axial furrows. Posterior branches of the facial sutures tend from the posterior corners of the eyes outward and slightly anteriorly; they curve posteriorly as they cross the lateral furrows and cut the margin just anterior to the level of the occipital furrows. Surface of the glabella smooth. Surface of the cheeks with many small round pits.

Thorax not represented in the Akpatok collection.

Pygidium preserved as a cast; of three segments; width more than twice the length; ends of pleura lie on straight line. Axis tapering fairly rapidly; with three annulations; anterior two distinct, posterior ring obvious but less distinct than the first two. Pleural lobes with three flattened spines; rib furrows deep and impressed. Pleura flattened; anterior pair curving backward; square ended; carinate; second pair curving; with a blunt angle on the anterior margin due to a sudden increase in curvature which is more rapid there than on the posterior margin; end with a blunt point; third pair of pleura with curved anterior margin and straight posterior margins; end in a point. Inter-pleural notches pronounced and decrease in size posteriorly. The ultimate segment is longer than its width and bears two pits posterior to the axis and on a line at right angles to it.

Billings' holotype of *C. icarus* is lost.[1] The species has been figured by Meek,[2] Barton,[3] Slocom,[4] Foerste,[5] and Troedsson.[6]

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[1] Personal Memorandum from Dr. E. M. Kindle, of the Geological Survey of Canada, April, 1933.

[2] F. B. Meek, "Pal. of Ohio," *Rep. Geol. Surv. Ohio*, i, 2, 1873, pl. xiv, figs. 11*a*, *b*, *c*.

[3] D. C. Barton, *Bull. Mus. Comp. Zool.*, liv, No. 21, 1913, pl. fig. 7.

[4] A. W. Slocom, *Iowa Geol. Surv. XXVth Ann. Rep.*, 1914, pl. xviii, fig 7.

[5] A. F. Foerste, "Upper Ordov. Faunas of Ontario and Quebec," *Mem. Geol. Surv. Canada*, 138, 1924, pl. xliv, figs. 3*a* and *b*.

[6] G. F. Troedsson, *Med. om Grønland*, lxxii, 1928, pl. xviii, figs. 10–15; pl. xix, figs. 1–3.

Meek's figure is a lithograph reconstructed from the photograph published later by Barton. There the characters of the pygidium are not brought out by the drawing for in the original specimen the pleural spines appear to be obscured. Foerste's specimens are a cranidium cast and small pygidium. Slocom's figure is the first to show the characters of the species with any success ; the specimen being complete but partially enrolled. Since Billings' type is lost and the writer has been unable to trace any figure of a specimen from Anticosti, the type locality, the species *C. icarus* (Billings) is interpreted in Slocom's sense.

Troedsson figured certain forms collected in North Greenland as *C. icarus* and through the courtesy of the Mineralogical Museum of the University of Copenhagen, the writer has been able to examine others from the same locality. It seems to the writer that Troedsson has included in this species certain forms that show constant differences from it. This is seen particularly in the pygidium but to a less extent in the glabella also. Two specimens from Akpatok Island show this same difference. Troedsson expresses his views as to variations in the pygidium in discussing *Ceraurus horridus* Troedsson.[1] "The pygidium described appears in two forms, a narrow and broad one. In the latter the axial portion projects less backwards, the pleural portion between the large pleurae being broader and shorter than in the former. These two forms suggest, of course, different species . . . the pygidia appear in different sizes independent of their shape, though the most giant specimen belongs to the broad type. The fact that both forms are equally represented in the collection . . . while the head-shields do not show specific difference, and there is no other species indicating the same kind of habitat, makes the present writer more inclined to consider them as being different sexes of one and the same species, the male being represented by the narrow, the female by the broad form."

In examining the pygidia of some of the Greenland species of *C. icarus* the writer reached the conclusion that there was sufficient variation in the spinose type of pygidium to account for sexual difference while a more distinct type still remained. He therefore proposes to describe the form as a new species.

Ceraurinus icarus is a Richmondian form in America. The Greenland specimens are "apparently" Richmondian and come from the Cape Calhoun beds. The Akpatok specimens range from sea-level to 450 feet. [A 4774–80.]

Ceraurinus daedalus sp. nov.

Pl. XX, Figs. 13–15.

Synonym : *Ceraurinus icarus* (Billings) pars. Troedsson, *Med. om Grønland*, 1928 (i.e. fig. 10, pl. xviii ; figs. 2 and 3, pl. xix).

Represented by one complete enrolled specimen and a glabella with part of the left fixed cheek in the Akpatok collection.

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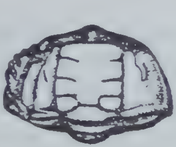
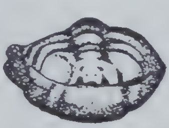
[1] Ibid., 67.

Specific diagnosis.—A *Ceraurinus* akin to *C. icarus* Billings, but differs in having glabella more than one-third the width of the cephalon ; with faintly convex sides ; square ended anteriorly with rounded corners : lateral glabellar furrows curving posteriorly rather more than is the case with *C. icarus.* Pygidium with the ends of the pleura lying on a very gentle arc ; pleura flattened, wide and blunt ; notch between second and third pleura small ; exceedingly slight notch between ultimate pleura which together form a telson-like plate, wider than its breadth.

Description.—Cephalon differs from *C. icarus* only in the points noted above.



1



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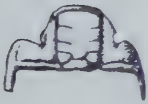

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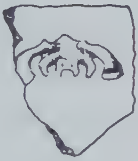

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FIGS. 1 and 2.—*Ceraurinus daedalus* sp. nov. Enrolled specimen. Holotype [A 4772]. The same specimen as Pl. XX, Figs. 14 and 15.

FIG. 3.—*Ceraurinus icarus* (Billings). The same specimen as Pl. XX, Fig. 7 [A 4774].

FIG. 4.—*Ceraurinus icarus* (Billings). Cast of pygidium. The same specimen as Pl. XX, Fig. 9 [A 4776].

All are natural size.

Thorax of eleven segments. Axial lobe less than one-third the width of the thorax ; tapering gently backward. Each pleuron is divided into an inner third and an outer two-thirds by a constriction ; inner third with a deeply impressed diagonal furrow. Pleural spines (?) short, flattened, and blunt, curving posteriorly.

Pygidium flat, of three segments ; width more than twice the length ; ends of pleurae lie on very gentle arc. Axis tapering fairly rapidly ; anterior two rings distinct. The ring-furrows end in pits. Rib-furrows between anterior and median pleura distinct ; not impressed ; between median and posterior pleura indistinct. Pleura flattened, square-ended with rounded corners ; contiguous at base ; anterior pair wide, increasing outward, carinate, curving through nearly 90°. Median pleura of equal width for all their length; free portion not curving. Notch between median and ultimate pleura small; notch between ultimate pleura exceedingly slight, consequently these two pleura have the appearance of a single telson-like plate, which is broader than its length and narrows very slightly posteriorly. Ultimate segment bears two pits, lying on a line at right-angles to the axis; these probably represent the ring-furrow between the third and fourth (vestigial and unrecognizable) segments.

Holotype.—Sedgwick Museum Cat. No. A 4772.

Horizon.—Richmondian, Akpatok Island, 350 and 400 feet. [A 4772–3.]

The differences from *C. icarus* are shown in the diagnosis. However, this new species, for which the name *daedalus* is proposed, possesses kinship with *C. icarus* as can be seen in the glabella. It seems to the writer that the forms figured by Troedsson in pl. xviii, fig. 10 and pl. xix, figs. 2 and 3 should be assigned to this species.

Note.—Four well-preserved hypostomes of the *Ceraurus-Ceraurinus* group were collected, but it is not possible to refer them to any definite species. [A 4801–4.] (Pl. XX, Fig. 12.)

PHACOPIDAE Corda.

Genus PTERYGOMETOPUS Schmidt.

Pterygometopus fredricki Slocom.

Pl. XX, Figs. 10–11.

Slocom, A. W., *Field Mus. Nat. Hist.*, Geol., Ser. IV, 67, pl. XV, figs. 8 and 9.

The genus *Pterygometopus* is represented by eight specimens; of these, six are pygidia, one is a fragment of the median portion of a glabella, and the other a fragment of the eye. The specimens are casts, with the exception of two pygidia, and none are complete.

In the glabella the anterior lobe is large and swollen; it rises abruptly from the anterior border; length probably more than half that of the glabella. The anterior lateral furrow runs backward at 70° to the axis. The second lateral furrow runs obliquely forward at an angle of 80° to the axis and is shallower than the first furrow and extends the same distance inward. The basal lateral furrows are obscured by a break, but appear to run forward slightly more obliquely than the second pair. A shallow furrow connects the end of the first lateral furrow with the basal furrow. The glabella is raised in a very slight rim anterior to the occipital furrow. The glabella is pustulose.

The portion of an eye was obtained from the same bed as the glabella. It shows five rows of facets, and although the specimen is fragmentary it is improbable that there were more than five.

The pygidia appear all to belong to the same species. They are rounded subtriangular in outline, convex, slightly produced posteriorly and strongly trilobed; the maximum width is slightly more than the length. Axis strongly convex, with margins slightly incurved; width at anterior end slightly less than one-third the width of the pygidium; gently tapering; abruptly rounded posteriorly; at least ten axial rings, sinuous and becoming less distinct posteriorly. Axial furrows narrow; distinctly impressed anteriorly; faint posteriorly, but appear completely to surround the axis. The axis bears a few tubercles. Side lobes slightly flattened anteriorly adjacent to the axial furrows; curve steeply downward laterally with convex surfaces, but become slightly concave near the margins anteriorly; with at least six segments. Interpleural furrows strongly impressed toward the axis but become fainter laterally and do not reach the margin. Pleural furrows impressed in the middle length of the pleura but efface before reaching either the axial furrows or the margin. The marginal border is therefore smooth.

The forms *P. callicephalus* Hall, *P. larrabeei* Slocom, *P. intermedius* Walcott, and *P. fredricki* Slocom are all somewhat similar. Slocom [1] has shown that *P. fredricki* has five rows of eye facets, while *C. larrabeei* and *P. callicephalus* have eight. This fact and the correspondence of the ten annulations on the axis and the six-eight pleural lobes with *P. fredricki* Slocom leads to identification with that form. Troedsson's fig. 14, pl. xix,[2] identified as *P. callicephalus* Hall, seems very similar to this species.

P. fredricki was described from the Lower Maquoketa beds at Clermont,[3] which are of Richmondian age. The species ranges from 350–400 feet on Akpatok Island. [A 4793–4800.]

The trilobite fauna of Akpatok Island is, then, definitely Richmondian. It compares closely, however, with only two described developments of the Richmondian; with the Cape Calhoun beds of North-West Greenland it has at least seven out of its thirteen species in common, and five are described from the Lower Maquoketa beds of Iowa.

A very noticeable feature is the small size of the Akpatok trilobites, especially in comparison with the Greenland material. The mode of preservation in these two cases is often very similar. All the specimens except three are "dead material", that is portions liberated by ecdysis, and occur with numerous other fossils in thin bands which are found spasmodically through the thickness of massive limestone.

The Maquoketa stage was divided by Savage [4] into Upper, Middle, and Lower members. Of these, the Lower consists of "alternating layers of slate and argillaceous limestone" ; the proportion of shale increases toward the top. The maximum thickness of the Lower member is 95 feet. Savage considered the Maquoketa Stage to be Trenton ; however, Ulrich[1] writes "that the Maquoketa, which overlies it (the Galena), is not older than Lower Richmond is proved (1) by the occurrence of a faunal zone characterized by *Clidophorus neglecta* and other small mollusks at its base at Dubuque, while the same zone is found *above* the Fernvale limestone, south of Saint Louis, and (2) by the position of the Fernvale in middle Tennessee, where it overlies the Leipers formation, which is the local representative of the Maysville group of the Cincinnati Section".

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[1] Slocom, "Trilobites from the Maquoketa Beds of Fayette County, Iowa," *Iowa Geol. Surv. XXVth Ann. Rep.*, 1914, Des Moines, 1916, 235.

[2] Troedsson, op. cit.

[3] Slocom, op. cit. 237.

[4] T. E. Savage, "Geology of Fayette County," *Iowa Geol. Surv. XVth Ann. Rep.*, 1904, 464, and table, 460.

TABLE.

Comparison of the trilobite fauna of Akpatok Island with that of (1) North-West Greenland and (2) the Lower Maquoketa Beds of Iowa.

Species from Akpatok Island.	*Cape Calhoun Beds, N.W. Greenland.*	*Lower Maquoketa Beds, Iowa.*
Isotelus iowensis Owen	+	+
Megalaspis beckeri Slocom		+
Illaenus eucentrus Troedsson	+	
Illaenus groenlandicus Troedsson	+	
Bumastus sp.		
Calymene cf. *fayettensis* Slocom		+
Calymene cf. *meeki* Foerste		
Calymene sp. of *meeki* group	? +	
Encrinurus sp.	? +	
Ceraurus horridus Troedsson	+	
Ceraurus tuberosus Troedsson	+	
Ceraurinus icarus (Billings)	+	+
Ceraurinus daedalus sp. nov.	+	
Pterygometopus fredricki Slocom	? +	+

"The geographic derivation of the fauna of the typical dark Maquoketa Shale is not positively determined. Though both the formation and its fauna are best developed in eastern Iowa, neither has been identified north of the United States, east of Wisconsin and Illinois, nor to the west of the 100th meridian. But as the fauna has its nearest relatives in the Utica, an unquestionable North Atlantic fauna, it is quite possible that the Maquoketa is represented in the supposed Utica on Georgian Bay and Hudson Strait, and that it invaded the Mississippi Valley from that direction."[2]

The writer is indebted to Professor O. T. Jones, F.R.S., and Mr. Philip Lake for reading the manuscript, and to Dr. F. R. Cowper Reed and Dr. C. J. Stubblefield for the benefit of their opinions on certain points.

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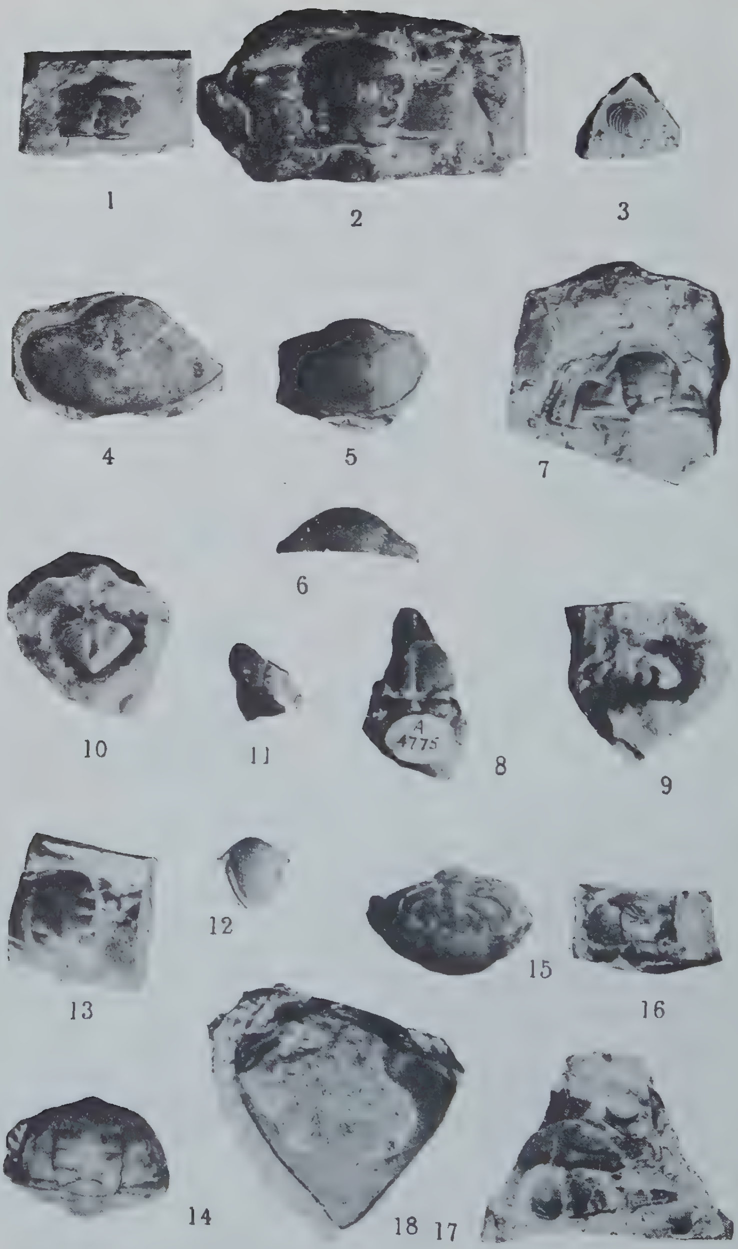
[1] E. O. Ulrich, "Revision of the Palaeozoic Systems," *Bull. Geol. Soc. Amer.*, xxii, 309, 1911.

[2] E. O. Ulrich, op. cit., 423.



Natural Size.

SOME RICHMONDIAN TRILOBITES FROM AKPATOK ISLAND.

To face p. 373.]

DESCRIPTION OF PLATE XX.

Fig.

1.—*Calymene* cf. *fayettensis* Slocom [A 4786].
2.—*Ceraurus horridus* Troedsson. Cast [A 4785].
3.—*Encrinurus* sp. [A 4768].
4.—*Illaenus groenlandicus* Troedsson. Pygidium [A 4762].
5.— ,, ,, ,, Cephalon, dorsal view [A 4761].
6.— ,, ,, ,, ,, posterior view [A 4761].
7.—*Ceraurinus icarus* (Billings) Slocom [A 4774].
8.— ,, ,, ,, ,, Cast [A 4775].
9.— ,, ,, ,, ,, ,, [A 4776].
10.—*Pterygometopus fredricki* Slocom. Cast [A 4794].
11.— ,, ,, ,, ,, of median portion of glabella [A. 4793].
12.—Cheirurid hypostome [A 4801].
13.—*Ceraurinus daedalus* sp. nov. [A 4773].
14 and 15.— ,, ,, ,, Holotype [A 4772].
16.—*Ceraurus tuberosus* Troedsson [A 4754].
17.— ,, ,, ,, Genal angle [A 4755].
18.—*Megalaspis beckeri* Slocom [A 4770].

***Throopella typa*, a new Devonian Scaphopod.**

By D. K. Greger.

(PLATE XXI.)

SCAPHOPODS are of rare occurrence in the Paleozoic of North America. *Dentalium* and *Plagioglypta* have been recorded from formations as old as Middle Devonian ; however, their occurrence is always sporadic and it is only in the Upper Carboniferous rocks that they are met with in any number. The form here described is the first Devonian occurrence of the Class that has come to the writer's notice throughout a period of thirty-five years' active collecting in the Devonian of the Mississippi Valley.

Throopella typa gen. et sp. nov.

Shell cylindrical, tapering at each end ; posterior end somewhat more attenuate ; the anterior end crateriform with an opening slightly oblique to the longitudinal axis. A collar or peristome is developed in the opening and extends over and folds back on the outside ; opening circular. The apical or posterior aperture is circular, oblique and simple, that is without clefts or slits.

The anterior aperture of *Throopella* is quite similar in structure to that of the modern *Cadulus*, especially so of the group typified by *C. obessus* Watson and *C. exiguus* Watson, the aperture being reduced within by a cingulum or callous ring which in the shell here considered reduces the caliber of the opening to approximately one-third.

Measurements of the Type Specimens.—Length 15·4 mm., diameter at equator 6·4 mm., diameter of anterior opening 1·6 mm., diameter of apical or posterior opening 0·8 mm. Exterior without ornamentation other than oblique growth lines.

Intimate Shell Structure.—Throughout the median three-fifths of the shell, its thickness is approximately 0·9 mm. Structurally the shell is arranged in three distinct layers; the outer layer is dense, fibrous, and 0·3 mm. in thickness. The median layer is porous or "chalky" with a thickness of 0·4 mm. The internal nacreous layer is very dense, its surface quite smooth and 0·2 mm. in thickness at the equator, increasing somewhat in thickness towards the ends of the shell (Fig. 7, Pl. XXI).

A section of the shell, heated to redness on a spatula and dropped into cold water, readily separates into its three components and the structural characters of each layer can be easily studied.

While the resemblance of *Throopella* to the modern *Cadulus* is quite obvious, the writer would hesitate to place it in the same group since the microscopic shell structure of *Throopella* is quite dissimilar, being nearer to that of the shell known to American collectors as *Plagioglypta canna*, from the Upper Carboniferous rocks. Its strikingly Caduliform resemblance we regard as only an instance of heteromorphy.

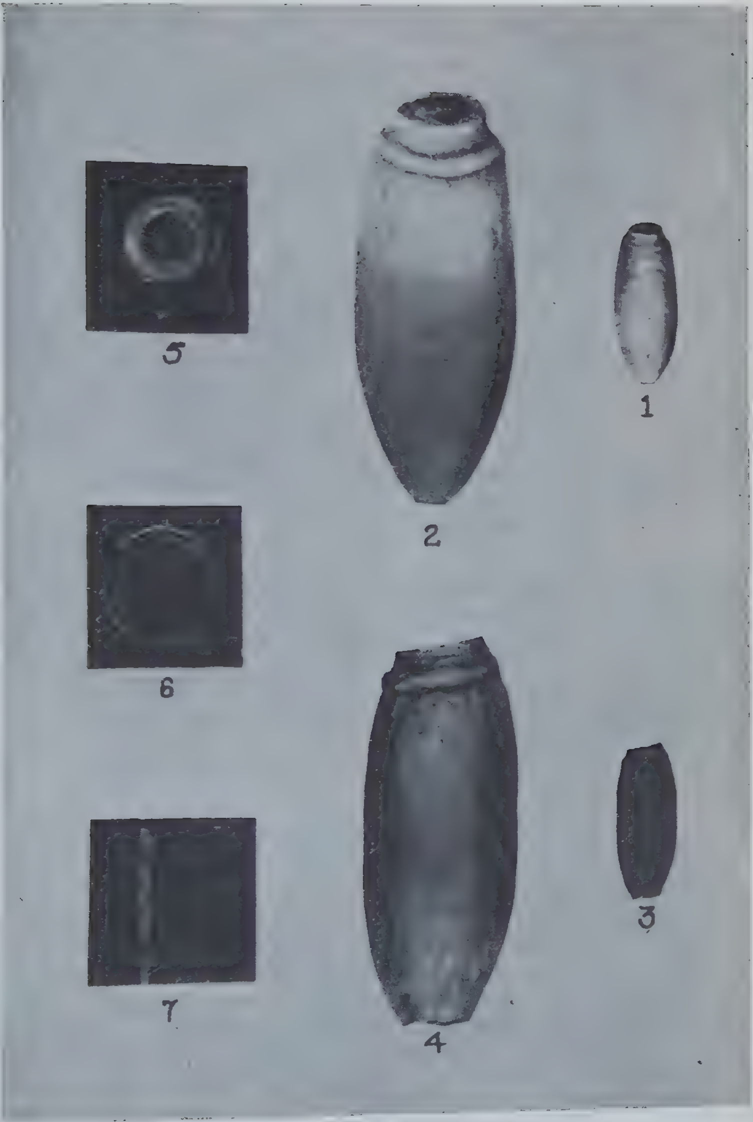
Geological Occurrence.—*Throopella typa* occurs rarely in a soft, limy yellowish shale in the Upper Devonian—Snyder Creek of Central Missouri, Zone No. 4 of the Cow Creek stage, as described in the writer's section in the *American Journal of Science*, xlix, 266, 1920.

The generic name is intended as an expression of sincere regard for Dr. Geo. R. Throop, Chancellor of Washington University, to whom the writer is indebted for friendly interest in paleontological research.

EXPLANATION OF PLATE XXI.

Fig.

1.—Dorsal view, slightly enlarged.
2.—Same, enlarged 3½ times.
3.—Profile of holotype, slightly enlarged.
4.—Same, enlarged 3½ times.
5.—Anterior opening, showing internal shelf or callous ring, enlarged 3½ times.
6.—Photomicrograph of transverse section, cut from near the equator of a mature shell.
7.—Photomicrograph of a longitudinal section of the same specimen, showing shell layers. The section is from the dorsal side, posterior to the equator, enlarged 10 times.



Throopella typa, a new Devonian Scaphopod.

[*To face p.* 374.

The Dusky Apatites of the Eskdale (Cumberland) Granite.

By Brian Simpson, M.Sc., University College, Swansea.

APATITE was first recorded from the Eskdale granite by R. H. Rastall and W. H. Wilcockson in 1915 (1).[1] Recently, the author, in carrying out work on the granite, has noticed the peculiar character of the apatites, in that they are mostly of a dusky type occasioned by the presence of large amounts of finely-divided inclusions. Similar apatites have been recorded from the Leinster granite (2), Gault Clay, Thanet Sands, Chausey Islands (3), Jersey (4), the Old Red Sandstone of the Cardiff District (5), and the Dublin district (6), but nearly all show a sharply defined core. The Eskdale ones, although presenting a dense centre, show no clear-cut division between the core and the outer zone of the apatite. Invariably the outer zone of the apatite carries some inclusions.

Four main varieties of apatites occur :—

(1) Rounded grains with a water-worn appearance.

(2) Irregularly fractured grains.

(3) Idiomorphic forms with $(10\bar{1}0)$, $(10\bar{1}1)$, (0001), and elongated parallel to *c*. This is the most common form.

(4) A second equant idiomorphic form, developing the same faces as (3).

A marked striation parallel to *c* is apparent in many crystals ; a basal parting is nearly always present along which a segregation of inclusions is seen. A. W. Groves notes this character in the apatite from Brittany, and from the plutonic rocks of Jersey. Frequently a faint colouring of the crystals is observed about the inclusions. This colour varies from a faint purple to brownish-yellow and greenish tint.

The inclusions are arranged in four types :—

(1) In strips parallel to *c*.

(2) As irregular central cores.

(3) Disseminated throughout the crystal with a central denser portion.

(4) Dense portion with shoots through the crystal. See Fig. 1.

Frequently the cores are faintly pleochroic, some from a greyish to brownish colour, others faintly in yellow, whilst a third appears greenish. The inclusions are minute and specific determination is impossible in most cases. However, those with a greenish tinge suggest finely-divided chlorite, an opinion held by Groves. In discussing the pleochroism, he offers an explanation which the present writer would support after seeing the Eskdale granite apatite forms. Groves writes : " Despite the different colours, the writer is of the opinion that the nature of the inclusions in most types, other than type *b*—chlorite and biotite—are similar, and that the different degrees and ranges of pleochroism are dependent on the size and arrangement of the fine particles of foreign matter."

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[1] The numbers in parentheses refer to Bibliography at end of article.

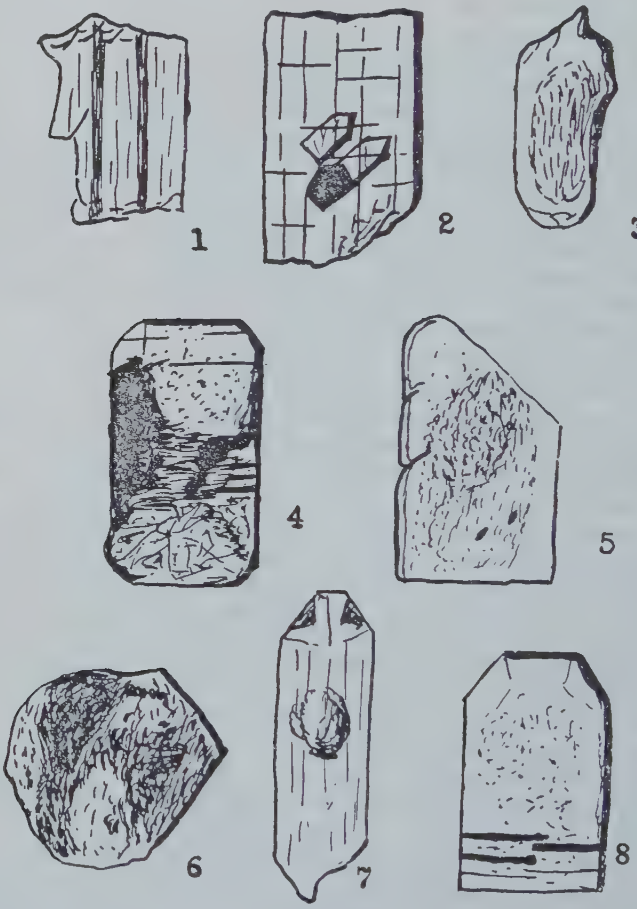

Fig. 1.

1. Irregular crystal with parallel bands of inclusions.
2. Crystal with longitudinal striation and included zircons.
3. Crystal with centrally placed inclusions.
4. Idiomorphic form-basal plane, pyramid, and prism, showing inclusions crowded to one side.
5. Slightly corroded form.
6. Irregular form crowded with inclusions.
7. Crystal elongated parallel to *c*.
8. Idiomorphic form with the inclusions crowded along the basal parting.

In the clear apatites, which are present in small quantities, zircon, rutile, and apatite are present as inclusions. Groves quotes Brammall's explanation for the formation of zones in zircons as follows: "The growth of a crystal X from its solution, creates a two-way migration of the molecules: (1) an inward diffusion of the constituents of X towards the centre of crystallization, and (2) an outward diffusion or repulsion of substances not required by X. Alien substances, thus repelled, tend to become concentrated in a narrow fluid zone around the margin of the crystal X, and for one of these substances say Y the concentration may reach labile stage, with the result that a crowd of crystalline Y particles may suddenly arise. As the precipitation of Y particles would automatically raise the concentration of X in the zone of precipitation, growth of X suddenly accelerated might overstep the Y particles and enclose them in a definite growth zone" (7). Groves, working from this theory, suggests that a similar explanation might be applied to the apatites, and that a sudden change in physical conditions might give the results he has observed in the apatite. The present writer is not able to agree with this, for, if such an explanation held, then there should be an inner core of clear apatite, which is not the case. Such an inner core is well displayed in a large phenocryst of orthoclase felspar from the St. Austell Granite near Luxulyan. In the diagram (Fig. 2) it will be noticed that there are several distinct zones of biotite within the crystal, but that the centre is clear orthoclase. Since orthoclase is present as phenocrysts, it must have begun to crystallize first, the magma being oversaturated with the components of orthoclase. In such a case, orthoclase would crystallize, repelling the unwanted material, as noted by Bramall, with the result that a zone of concentration would arise and biotite would crystallize out until equilibrium was again reached. The result would be a rythmic crystallization of biotite and orthoclase.

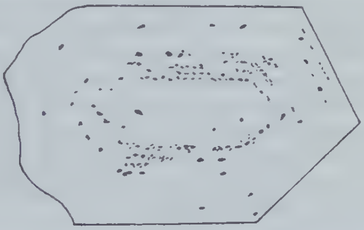

Fig. 2.—Crystal of orthoclase from the St. Austell Granite, Luxulyan. Showing zonal disposition of biotite and orthoclase.

Although this theory applies to the case of the zircons and felspars, it does not seem to fit that of the apatites from Eskdale, for here there is no rhythmic disposition of the inclusions, which are widespread throughout the crystal; in addition, the concentration of these inclusions is not always central, but may be displaced to one of several positions. These facts seem to indicate that in the case of the Eskdale apatites, at least, the small inclusions were there prior to the crystallization of the apatite and were incorporated in that mineral on crystallization, rather than being the product of simultaneous crystallization as described by Brammal for the zircons.

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(1) R. H. Rastall and W. H. Wilcockson, *Quart. Jour. Geol. Soc.*, lxxi, 1915, 607–8.
(2) W. F. Flett and F. Smithson, Geol. Mag., LXV, 1928, 14–19.
(3) A. W. Groves and A. E. Mourant, *Min. Mag.*, xxii, 1929, 92–99.
(4) A. W. Groves, Geol. Mag., LXIV, 1927, 244–9.
(5) H. Heard and R. Davies, *Quart. Jour. Geol. Soc.*, lxxx, 1924, 505.
(6) F. G. Smithson, Geol. Mag., LXV, 1928, 14–19.
(7) op. cit. 3.

REVIEWS.

The Jurassic System in Great Britain. By W. J. Arkell, M.A., D.Ph., B.Sc. pp. xii + 681, with 41 plates and 97 text-figures. Oxford : Clarendon Press ; London : Oxford University Press, 1933. Price 30*s*. net.

THE merits of this remarkable book place it at once among the classics of stratigraphical literature. When Dr. Arkell embarked upon his courageous enterprise, he probably did not realize the magnitude and difficulty of the task he had set himself. Let it be said at the outset that he has proved himself equal to the responsibility undertaken. Critical treatment combined with sound judgment, aided by the art of marshalling complex details without confusion and expressing results clearly, have enabled him to produce an illuminating work, a model of its kind.

The reproach has lain long on British geologists that there has been no adequate modern account of the rock-succession in their own country, made classic by William Smith more than a century ago and by the pioneers who soon followed him. The cardinal principles of stratigraphical geology formulated by William Smith, a priceless heritage on which to build, as shown by their subsequent application throughout the world, were drawn to a large extent from observations on the Jurassic outcrops in England. H. B. Woodward's comprehensive work (*The Jurassic Rocks of Britain* [excluding Yorkshire], 1893–5) was marked by many shortcomings which need not be dilated on here. Its imperfections were always obvious, even at the time of publication, and the blame should not be entirely ascribed to that amiable and much regretted author, a master in the art of geological mapping. A work of such scope produced at official behest, in circumstances far from favourable, could not be otherwise than faulty, and Woodward, of an older school, was slow to adapt himself to a quickly changing outlook. The account of the Jurassic rocks of Great Britain contributed by Professor A. Morley Davies to the *Handbuch der Regionalen Geologie*, and the later *Handbook of the Geology of Great Britain* (1929), marked a great advance, and embodied most usefully the chief results of modern work; but within the narrow limits of space available it was only possible to give a brief and condensed, synoptic presentation.

The rapid advances in knowledge, the application of more and more refined methods, and the formidable growth of the special literature during the last forty years, have rendered the task of the present-day chronicler of British geology vastly more complex than that which confronted Woodward. Fortunately, Dr. Arkell could approach his arduous undertaking without the drawback of official trammels and preoccupations; and with the fresh outlook of youth, with an enthusiasm persistent and undismayed, and with the requisite leisure and other personal advantages, he has been able to pursue the work in his own manner.

Throughout this book, innumerable difficulties of all kinds, and arguments for their solution, are discussed in a simple way. There are no wordy evasions. The picture is drawn with firm strokes, and all is left sharply in focus; at the same time, the working of an alert critical faculty is in evidence throughout. This direct and decisive method gives the work a character by which it becomes contrasted most strikingly with Woodward's discursive and rambling treatise. It is indeed remarkable to find to what an extent the author, confronted by so many thorny problems, has succeeded in avoiding vagueness and indecision. This clarity, both of thought and of presentation, is an outstanding character of the book and renders it most convincing and attractive. Yet there is nowhere any overstatement, or the hint of any undue claim that the final word has been spoken.

In parts i and ii of the volume many matters of prime importance in stratigraphical investigations are discussed in a suggestive and instructive manner. The growth of the classifications is carefully examined, the terms introduced from time to time for stratal and chronological subdivisions are compared and defined, and the author, with a firm hand, produces order in what has been a veritable chaos, and resolves the many inconsistencies that have resulted from careless thinking and the inconsiderate use of this part of the language of the science. The result is a salutary corrective. Appendix II, p. 617, containing a list of no less than 120 stage-names hitherto proposed for parts of the Jurassic system, to a great extent inconsistent and overlapping, alone suffices to justify the severity of some of the criticisms.

Part ii deals with the problems of sedimentation in their relation to the tectonic history of the period, and here will be found some illuminating discussions. In visualizing the passage of events which resulted in the particular stratal successions now present in different districts, of a continuous or interrupted character as the case may be, the author, both here and in succeeding chapters, considers these developments in relation to the repeated movements of depression or elevation, both on the narrower and broader scale. He has devoted much thought to these important aspects of the subject, and the account he has given provides profitable reading. Indeed, parts i and ii of this book are to be recommended for study, not only by those interested in Jurassic geology, but by all who are engaged in stratigraphical work.

To say that the first ninety-seven pages contain many of the best things in this volume is not to withhold admiration from the remainder. The accounts of the formations set forth in part iii are excellent; they are full and up-to-date, and yet are not overloaded with local descriptive detail. Here Dr. Arkell has enlisted a certain amount of help, and in submitting sections of his manuscript to different geologists whose criticisms might be of value, he did wisely. The assistance he received by the collaboration of Mr. L. Richardson in some of his field-studies is duly acknowledged. But throughout these stratigraphical chapters, abundant proof is given of the great amount of first-hand information possessed by the author himself and of the innumerable field-observations made by him. The result is an admirable review of our present-day knowledge. This is followed (in part iv) by a discussion of some palaeogeographical considerations, frankly falling more within the realm of speculation, but none the less of great interest. The useful classified bibliography with which the work concludes occupies nearly fifty pages.

Throughout the chapters of this volume there is to be found good and ample documentation. The illustration of the work is on a generous scale, and the many text-figures are well chosen and executed. There are upwards of fifty views of geological subjects, well reproduced in half-tone process. If a few of these fall short of photographic perfection, in the main they are an excellent selection and fulfil their purpose adequately. A welcome feature is a set of plates illustrating the chief ammonites used as zonal index-species, and certain other fossils of Rhaetic and Purbeck Age. To say that most of these photographic illustrations of fossils are from negatives made by Mr. J. W. Tutcher is sufficient guarantee of their excellent quality.

Faults of omission are few, having regard to the scope of the work. An example is seen on p. 98, where Mr. Richardson is credited with the assignment of the Tea Green Marls to the Keuper. The fact that this ascription had been made some years previously by E. Wilson seems to have been overlooked. We miss also any discussion of Dr. R. L. Sherlock's contention that the Rhaetic Beds are conformable to the Keuper. Errors of citation are not numerous, though a few are to be found. On p. 8, the title and date of Fitton's "great memoir" are both wrongly given. On p. 297 (n. 2), pl. cdlii should read pl. cdliii; on p. 371 (n. 2) pl. cdxxxvii should read pl. dxlviii; on p. 457 (n. 2) the specimen said to be in the Oxford University Museum is actually in the Museum of Practical Geology, London, and "(pl. xxxix)" cited here should read "(pl. xl)"; on p. 514 (n. 1), "p. cccv" should read "pl. cccv." Misprints such as "Guildford" for "Guilford" (p. 339) are fortunately rare.

A worse fault, in the present reviewer's opinion, is the meagre character of the subject index. This book is sure to be used by many, and indeed chiefly, as a work of occasional reference, and there should be no need for lengthy explorations through a bulky text when it is so consulted. The index is found to fail when put to numerous tests; we see only four entries under the letter E, and only two items under J, K, and N, respectively. A subject-index even six times as long would not be too full, having regard to the size and importance of the work. Its preparation would probably condemn the author to a month's hard labour (for he could best compile it), but this should be the outstanding improvement in a future edition.

The volume has been beautifully produced by the Oxford University Press, in a manner worthy of the fine quality of its contents. By its publication, Dr. Arkell has rendered a signal service to British geology, for which he must be warmly congratulated It is to be hoped that the example he has set may prove a stimulus to others to treat with similar skill and lavish care the rest of the geological systems in this country, a land favoured by such fullness and variety of stratigraphical representation.

F. L. KITCHIN.

THE FOSSIL CARNIVORA OF INDIA. By GUY E. PILGRIM, D.Sc. Palaeontologia Indica (New Series), Vol. XVIII. pp. iii + 232. Calcutta (Government of India), 1932. Price 22*s*. 6*d*.

THIS fine memoir is based on the results of prolonged study of the ossiferous deposits of India, the strata of which are now classified according to their age in a continuous series extending from the Lower Miocene (Burdigalian) to the Lower Pleistocene, but not including either the Narbada and Godavari alluvium or the cave deposits which represent the Middle and Upper Pleistocene. The approximate European equivalents of the various Indian stages are given in a table. The author also enters into a comparison of the Indian forms with those of China and points out how in certain respects (e.g. in the presence of Mellivorines) India agrees with China and differs from Europe. On the other hand, the Lutrine affinities are nearer to European than to Chinese forms. It is shown further that a number of migrants to China from N. America (especially certain species of Caninae) had not penetrated either into Europe or into India in Pontian times, but that by the Pinjor stage (Upper Pliocene) the N. American carnivores had entered

India. Nevertheless, India retained numerous archaic genera such as *Agriotherium* (one of the Ursidae), *Hyaenictis* (a genus which is supposed to have taken origin near the main stem of the hyaenoid ancestor), *Enhydriodon* (a primitive mustelid), and *Vishnuictis* (a primitive viverrid). The work is very complete, containing as it does a description of nearly a hundred species. The nine full-page plates are beautifully executed; there is a table showing the suggested phylogeny of the Hyaenidae and a very full bibliography.

F. H. A. M.

DIE BODENSCHÄTZE DEUTSCHLANDS. By E. KRENKEL. Vol. i, pp. 301, with 71 illustrations. Berlin: Borntraeger, 1932. Price RM. 22·50.

IT is stated in the preface to this work that it was originally planned on a much larger scale, but that owing to prevailing economic conditions considerable retrenchment was necessary. The present volume begins with a chapter of 22 pages giving a candid account of the mineral resources of the Reich, which in some important particulars are very limited; it would appear that in nearly everything except coal and potash imports greatly exceed home production. A very brief summary, less than a page, of German oil production will be of interest to British geologists, to whom such information is not always easily accessible. It appears that up to the end of 1929 the total production of oil in Germany was about 2,000,000 tons, mostly from Hanover. The geology of this oil-field, where the oil is often associated with Permian salt-domes, is very interesting. The actual oil-bearing horizons are Rhaetic-Lias boundary beds, Lower and Upper Dogger (= Middle and Upper Jurassic) and Lower Cretaceous.

Following a short account of German mining regulations and of Kartels, employers' and trades unions, workers' insurance schemes, and so on, the rest of this volume is occupied by a detailed account of the deposits of coal, lignite, and peat, with abundant geological and statistical information.

R. H. R.

CORRESPONDENCE.

PROFESSOR HOLMES' HYPOTHESIS OF THE GENESIS OF LEUCITE AND MELILITE ROCKS.

SIR,—In answer to Dr. Holmes' letter in your March number, I wish to point out that in his original statement of the hypothesis (*Q.J.G.S.*, 1932), Dr. Holmes used the expression "primary peridotite magma" three times and "primary peridotite" six times. He now explains that he considers the parent peridotite magma of the leucite and melilite rocks to be largely derived from " re-fusion of the crystalline uppermost part of the Lower Layer ". Ought he in that case to have called it a *primary* magma ?

On the question of the determination of traces of the rarer constituents, Dr. Harwood has failed to notice that my criticism referred to gravimetric methods, not to the much more delicate colorimetric ones. I had in mind especially baria and strontia, since these oxides were used by Holmes to sustain his argument. Dr. Harwood admits that he is not prepared to defend the accuracy of the strontium determination as at present carried out, and that errors of 25 per cent and even 50 per cent may sometimes occur in the determination of other minor constituents ; that is, he concedes everything that I claimed. I did not criticize the *principle* of comparative geochemical studies, but only the accuracy of the available data.

Mr. Golding thinks my criticism is unfair to the chemists, and defends the alcohol-ether method of determining strontia. I refer him to Dr. Harwood's opinion and to a paper by W. Noll (*Zeit. Anorg. Chem.*, 1931, p. 193), who shows that errors of 40 per cent are possible by this method. I did not and do not blame chemists for the fact that certain constituents are difficult to determine accurately, but I wished to bring home to geologists the very doubtful quality of some of the data on which Professor Holmes based his theory.

S. J. SHAND.

STELLENBOSCH, S. AFRICA.
4th April, 1933.

THE AGE OF THE FORD BEDS OF PEMBROKESHIRE.

SIR,—In their paper on " The Pre-Cambrian and Cambrian Rocks of Pembrokeshire ", *Q.J.G.S.*, 1912, Professor O. T. Jones and Dr. H. H. Thomas tentatively referred the Ford Beds to " that position of the Upper Solva Group which is not far removed from the Menevian."[1] This identification was made on lithological grounds, assiduous search having failed to reveal any fossils, but its correctness has recently been confirmed by the discovery of a small fauna of Middle Cambrian age.

In the spring of 1932 Professor O. T. Jones conducted an excursion of the Sedgwick Club from Cambridge University to Western Pembrokeshire and a visit was paid to the section of Ford Beds exposed in the railway cutting at Wolf's Castle Halt. These beds are probably in a considerably more weathered condition than when originally searched for fossils and immediately behind the south-west corner of the shed upon the railway platform, about 7 feet above the base of the exposure, specimens of the following fossils were found by Miss F. E. S. Caldwell, Mr. M. Black, and myself:—

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[1] *Q.J.G.S.*, lxvii, 1912, 399.

Agnostus exaratus Grönwall
Solenopleura applanata Salter
and a horny brachiopod.

The presence of these trilobites, whose identification has been confirmed by Mr. Philip Lake, indicates that this portion of the Ford Beds may be referred to the zone of *Paradoxides hicksi* in the Middle Cambrian. It is quite consistent with the position assigned to the Ford Beds in the paper quoted above.

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Geological Survey Work in Malaya.

The Annual Report of the Federated Malay States Geological Survey Department for 1932 contains the information that an examination has been carried out of a considerable tract of hilly, jungle-clad country in the eastern part of Kinta in order to determine the extent of a band of highly metamorphosed schist which is now known to be interstratified with the crystalline limestone in two localities. The schist is found in a north-and-south belt near the margin of the great granite intrusion, and its association with scheelite in one locality and with tin deposits in others justifies further work on the subject.

During the year inquiries were answered about tin, gold, glass-sand, coal, iron, kaolin, limestone, and many other materials, and identifications of minerals and rocks were made on samples sent from the F.M.S. and other countries. An important part of the Department's work is now that of examining all prospecting results, old and recent, and a permanent record is being prepared. The value of this work to miners is self-evident, and there seems a likelihood that it may also be of great assistance to the Government in deciding upon the alienation of land.

Editorial Note.

In the note on Glacial Boulders at Verulamium in the last number the author inadvertently omitted to express his indebtedness to Dr. R. E. Mortimer Wheeler who kindly supplied the text-figure of Verulamium, which was reproduced through the courtesy of *The Times*.